CONTRACTOR'S REPORT

DSS CONTRACT 12SC.KE201-4-P082

FINAL REPORT

ANAEROBIC/AEROBIC TREATMENT OF WET CARBONIZATION PRESSATE From MAINE SUNKHAZE AND CHEMO BOG PEATS

CONTRACTOR: ADI LIMITED
1115 REGENT STREET
FREDERICTON, N. B.
E3B 4Y2

SCIENTIFIC AUTHORITY (PROJECT MANAGER): MR. MICHAEL GUILCHER
ENVIRONMENTAL PROTECTION SERVICE
ENVIRONMENT CANADA
ATLANTIC REGION
5TH FLOOR, QUEEN SQUARE
45 ALDERNEY DRIVE
DARTMOUTH, N. S.
B2Y 2N6

TABLE OF CONTENTS

		PAGE
ABSTRACT		ix
RÉSUMÉ		xi
LIST OF ABBREVIATIONS AND SYMBOLS		xv
1.0	CONCLUSIONS AND RECOMMENDATIONS	1
	1.1 Conclusions	1
	1.1.1 Anaerobic Study Conclusions	1
	1.1.2 Nitrification Study Conclusions	4
	1.2 Recommendations	6
2.0	INTRODUCTION	7
3.0	OBJECTIVES	9
4.0	CHARACTERISTICS OF WET CARBONIZATION PEAT PRESSATE	11
	4.1 General	11
	4.2 Wet Carbonization Peat Pressate	12
5.0	BENCH-SCALE MODELS	14
	5.1 Bulk Volume Fermenter	14
	5.2 Feed, Recycle and Biogas Systems	15
	5.3 Nitrification-Activated Sludge Models	15
6.0	MODEL OPERATIONS	22
	6.1 Seeding and Startup - BVF	22
	6.2 BVF Operations	23
	6.3 Seeding and Startup of Nitrification Models	24
	6.4 General Operation of Nitrification Models	26
	6.5 Analyses	26
7.0	RESULTS	33
	7.1 BVF	33
	7.2 Operations Data: Nitrification-Activated Sludge Models #1 and #2	39
	7.3 Nitrogen Data: Nitrification-Activated Sludge Models #1 and #2	39
	7.4 Carbonaceous and Solids Data: Nitrification-Activated Sludge Models #1 and #2	44
	7.5 Nitrogen Mass Balance Data: Nitrification-Activated Sludge Models #1 and #2	50

TABLE OF CONTENTS (CONT'D)

		PAGE
	7.6 Overall System Performance	50
8.0	DISCUSSION OF RESULTS	71
	8.1 Performance of the BVF	71
	8.2 Discussion of Operational Data: Nitrification-Activated Sludge Models #1 and #2	78
	8.3 Discussion of Nitrogen Results: Nitrification-Activated Sludge Models #1 and #2	81
	8.3.1 General	81
	8.3.2 Nitrification-Activated Sludge Model #1	82
	8.3.3 Nitrification-Activated Sludge Model #2	83
	8.4 Discussion of Carbonaceous and Solids Results: Nitrification-Activated Sludge Models #1 and #2	84
	8.5 Discussion of Nitrogen Balance Data: Nitrification-Activated Sludge Models #1 and #2	84
	8.6 Potential Fish Toxicity of Ammonia Nitrogen and Nitrite Nitrogen	87
9.0	PARTIAL MASS AND ENERGY BALANCE	90
10.0	ECONOMIC ANALYSES	93
REFERENCES	. . . . .	94
APPENDIX A	RAW PEAT PROCESSING CONDITONS	95
APPENDIX B	BVF #1 INFUENT AND EFFLUENT DATA	97
APPENDIX C	OPERATIONS AND LOADING DATA: NITRIFICATION-ACTIVATED SLUDGE MODELS #1 AND #2	101
APPENDIX D	NITROGEN DATA: NITRIFICATION-ACTIVATED SLUDGE MODELS #1 AND #2	105
APPENDIX E	CARBONACEOUS AND SOLIDS DATA: NITRIFICATION-ACTIVATED SLUDGE MODELS #1 AND #2	107

TABLE OF CONTENTS (CONT'D)

		PAGE
APPENDIX F	NITROGEN MASS BALANCES: NITRIFICATION-ACTIVATED SLUDGE MODELS #1 AND #2	109
APPENDIX G	CARBONACEOUS AND SOLIDS REMOVALS: NITRIFICATION-ACTIVATED SLUDGE MODELS #1 AND #2	117
APPENDIX H	PRELIMINARY, FULL-SCALE BVF DESIGN CRITERIA AND ASSUMPTIONS	119
APPENDIX I	PRELIMINARY BVF CAPITAL COST ESTIMATES . . .	121
APPENDIX J	PROJECTED ANNUAL OPERATING AND MAINTENANCE COSTS ESTIMATES (BVF ONLY)	123

LIST OF FIGURES

5.1	BVF System Schematic	18
5.2	Nitrification-Activated Sludge Systems Schematic .	19
5.3	BVF #1 - Section	20
5.4	Nitrification-Activated Sludge Model #1 Section .	21
7.1	COD and BOD Concentrations	54
7.2	COD and BOD Loadings	55
7.3	COD and BOD Removals	56
7.4	SS and VSS Concentrations	57
7.5	SS and VSS Loadings	58
7.6	SS and VSS Removals	59
7.7	VA Concentrations, Influent and Effluent	60
7.8	pH Values, Influent and Effluent	61
7.9	Alkalinity Concentrations, Influent and Effluent .	62
7.10	TKN and NH_3-N Loadings: Nitrification-Activated Sludge Models #1 and #2	63
7.11	COD and BOD Loadings: Nitrification-Activated Sludge Models #1 and #2	64
7.12	Influent/Effluent Nitrogen Data: Nitrification-Activated Sludge Model #1	65
7.13	Influent/Effluent Nitrogen Data: Nitrification-Activated Sludge Model #2	66

LIST OF FIGURES (CONT'D)

		PAGE
7.14	Influent/Effluent COD and BOD: Nitrification-Activated Sludge Model #1	67
7.15	Influent/Effluent SS and VSS: Nitrification-Activated Sludge Model #1	68
7.16	Influent/Effluent COD and BOD: Nitrification-Activated Sludge Model #2	69
7.17	Influent/Effluent SS and VSS: Nitrification-Activated Sludge Model #2	70
9.1	Partial Mass and Energy Balance; Wet-Carb Process	91

LIST OF TABLES

4.1	Raw Peat Slurry and Peat-Derived Fuel Characteristics	11
4.2	Analysis of Raw Wet-Carb Peat Pressate	13
6.1	BVF #1 - Model Operations	28
6.2	Summary of Seeding and Start-Up Events for Nitrification-Activated Sludge Models	30
6.3	Analytical Test/Frequency Schedule	31
6.4	Analytical Procedures	32
7.1	BVF #1 - TKN, NH_3-N, Total P Data	35
7.2	BVF #1 - Total Sulfide Data	36
7.3	Gas Composition Data	37
7.4	BVF #2 - Effluent pH, VA and ALK	38
7.5	Summary of Operations Data: Nitrification-Activated Sludge Models #1 and #2	40
7.6	Summary of Influent Nitrogen Data: Nitrification-Activated Sludge Models #1 and #2	41
7.7	Selected Nitrogen Data: Nitrification-Activated Sludge Model #1	45
7.8	Selected Nitrogen Data: Nitrification-Activated Sludge Model #2	46
7.9	Summary of Selected Nitrogen Data: Nitrification-Activated Sludge Models #1 and #2	47
7.10	Summary of Carbonaceous and Solids Data: Nitrification-Activated Sludge Model #1	48
7.11	Summary of Carbonaceous and Solids Data: Nitrification-Activated Sludge Model #2	49

LIST OF TABLES (CONT'D)

		PAGE
7.12	Nitrogen Mass Balance Data: Nitrification-Activated Sludge Model #1	51
7.13	Nitrogen Mass Balance Data: Nitrification-Activated Sludge Model #2	52
7.14	Average Overall Removals: Anaerobic Influent to Final Aerobic Effluent	53
8.1	Comparision of VA Results by Titration and Gas Chromatography	72
8.2	BVF #1 Suspended and Volatile Suspended Solids Data	75
8.3	Summary of Carbonaceous and Solids Removals: Nitrification-Activated Sludge Models #1 and #2	85
8.4	Un-ionized Effluent NH_3-N Concentrations:	
B.2	COD, BOD, SS, VSS Removals and Loadings: BVF #1 .	98
B.3	pH, VA, ALK Concentrations: BVF #1	99
C.1	Operations Data: Nitrification-Activated Sludge Model #1	101
C.2	Operations Data: Nitrification-Activated Sludge Model #2	102
C.3	Loading Data (TKN, NH_3-N, COD, BOD): Nitrification-Activated Sludge Model #1	103
C.4	Loading Data (TKN, NH_3-N, COD, BOD): Nitrification-Activated Sludge Model #2	104
D.1	Influent and Effluent Nitrogen Data: Nitrification-Activated Sludge Model #1	105
D.2	Influent and Effluent Nitrogen Data: Nitrification-Activated Sludge Model #2	106
E.1	Carbonaceous and Solids Data: Nitrification-Activated Sludge Model #1	107
E.2	Carbonaceous and Solids Data: Nitrification-Activated Sludge Model #2	108
F.1	TKN Mass Balance: Nitrification-Activated Sludge Models #1	109
F.2	NH_3-N Mass Balance: Nitrification-Activated Sludge Model #1	110
F.3	NO_3-N Mass Balance: Nitrification-Activated Sludge Model #1	111
F.4	NO_2-N Mass Balance: Nitrification-Activated Sludge Model #1	112

LIST OF TABLES (CONT'D)

		PAGE
F.5	TKN Mass Balance: Nitrification-Activated Sludge Model #2	113
F.6	NH_3-N Mass Balance: Nitrification-Activated Sludge Model #2	114
F.7	NO_3-N Mass Balance: Nitrification-Activated Sludge Model #2	115
F.8	NO_2-N Mass Balance: Nitrification-Activated Sludge Model #2	116
G.1	Carbonaceous and Solids Removals: Nitrification-Activated Sludge Model #1	117
G.2	Carbonaceous and Solids Removals: Nitrification-Activated Sludge Model #2	118

ABSTRACT

A two-stage anaerobic-aerobic study was undertaken at the laboratory level to assess the treatability of wet carbonization peat pressate using the ADI-BVF for the anaerobic stage and two nitrification-activated sludge models for the aerobic portion. The anaerobic portion of the study operated for twenty weeks while the aerobic portion operated for thirteen weeks. Performance of the BVF was assessed as the organic loading was progressively increased. The degree of nitrification in the aerobic models was assessed at two different HRTs and three different operating temperatures.

The results of this study revealed the following:

1. Wet carbonization peat pressate is very amenable to anaerobic-aerobic treatment;

2. Typical COD/BOD removals in the anaerobic reactor were in the range of 60-70/80-90 percent; overall COD/BOD removals through both stages were typically 70-75 /96-98 percent;

3. There was no evidence of biological toxicity;

4. The average methane concentration was approximately 65 percent, with a specific methane generation rate of 0.27 m^3 CH_4 (STP)/kg COD removed;

5. Micro and macronutrient addition will not be required with anaerobic pretreatment, while chemicals for pH control will definitely be needed for stable operation in the BVF;

6. BVF sludge wasting will be required after 1.5 to 2 years;

7. Nitrification of the anaerobic effluent is necessary to reduce the ammonia concentrations to nontoxic levels;

8. Nearly complete nitrification can occur at temperatures as low as 15°C;

9. There is still the potential for fish toxicity from ammonia (and nitrite) even after nitrification treatment; the likelihood for nitrite toxicity is believed to be greater.

RESUME

Une étude d'anaérobie-aérobie a été conduite au laboratoire a fin d'evaluer le degré du traitement de carbonisation mouillée de la tourbe pressée. L'ADI-BVF a été utilisé pendant l'étude anaérobie, tandis que deux cellules de boues activées à nitrification ont été utilisées pendant l'étude aérobie. L'étude anaérobie a duré vingt semaines tandis que l'étude aérobie a pris treize semaines. Le fonctionnement du BVF a été observé pendant que la charge organique a été graduellement augmentée. Le degré de nitrification dans les cellules aérobies a été evalué pendant deux differents temps de retention hydraulique (HRTs) et à trois differentes températures d'opération.

Les resultats de cette étude indiquent que:

1. La carbonisation mouillée de tourbe pressée se convient bien au traitement anaérobie-aérobie.

2. Les reductions de DCO/DBO dans le réacteur anaérobie étaient dans l'ordre de 60 à 70/80 à 90 pourcent. Réductions générales a travers les deux étapes étaient dans l'ordre de 70 à 75/96 à 98 pourcent.

3. Il n'y avait aucune évidence de toxicité biologique.

4. La concentration moyenne du methane dans le "biogaz" était approximativement 65 pourcent avec un taux de production de méthane de 0.27 m^3 CH_4(STP)/kg COD réduit.

5. Addition des substances nutritives n'est pas nécessaire pour le pré-traitement anaérobie; tandis que des produits chimiques, pour contrôler le pH, sont definitivement nécessaire pour aboutir à une opération stable dans le BVF.

6. L'élimination des boues qui vont s'accumuler dans le BVF sera nécessaire après 1,5 à 2 ans d'opération.

7. La nitrification d'effluent anaérobie est nécessaire pour reduire la concentration d'ammoniac jusqu'à un niveau nontoxique.

8. Presque complète nitrification peut être obtenu à une température aussi basse que 15°C.

9. Même après un traitement de nitrification, il est possible que poissons sont exposés à des éléments toxiques provenant de l'ammoniac (et nitrate); la possibilité que les nitrates soient plus toxique est grande.

LIST OF ABBREVIATIONS AND SYMBOLS

a	annum
ALK	alkalinity
*BODT	total biochemical oxygen demand
BVF	bulk volume fermenter
CODD	soluble chemical oxygen demand
*CODT	total chemical oxygen demand
d	day
EFF (or eff)	effluent
g	gram
GC	gas chromatograph
GJ	gigajoule
HRT (or DT)	hydraulic retention time
INF (or inf)	influent
i.d.	inside diameter
kg	kilogram
kJ	kilojoule
kWh	kilowatt-hour
L	litre
LT	less than
m	metre
mg/L	milligram per litre
MJ	megajoule
mm	millimetre
NRC	National Research Council
o.d.	outside diameter
PDF	peat derived fuel
ppb	parts per billion
ppm	parts per million
SD	standard deviation
SS	suspended solids
STP	standard temperature and pressure

LIST OF ABBREVIATIONS AND SYMBOLS (continued)

t	metric tonne
TKN	total kjeldahl nitrogen
TS	total solids
TVS	total volatile solids
ug/L	micrograms per litre
VA	volatile acids
VSS	volatile suspended solids
~	approximately

* when expressed as COD or BOD, CODT or BODT is implied

1.0 CONCLUSIONS AND RECOMMENDATIONS

1.1 Conclusions

The major conclusions from this anaerobic-aerobic treatability study on wet carbonization peat pressate follow in point form. Regarding the assessment of anaerobic treatability, many of the conclusions from the previous study[1] on WETOX^R peat pressate also apply here.

1.1.1 Anaerobic Study Conclusions

1. The data from this study show quite conclusively that wet carbonization peat pressate is treatable, anaerobically, and to a high degree of stabilization.

2. For a full-scale application of the BVF technology to this waste, a design COD loading of 2.0 kg/m^3.d for a removal of 65 percent (85 percent BOD) would be reasonable (this loading was used here to develop full-scale BVF capital costs). Data from this study suggest that the BVF can take COD loadings of 2.5 kg/m^3.d and possibly higher for at least short periods of time.

3. The practical limits of COD, BOD and SS removals are in the range of 60-70 percent, 80-90 percent and 50-60 percent, respectively. With the exception of SS removals, this range of removals is identical to those found with the WETOX^R waste.

4. The energy credit from the biogas represents approximately 5.5 percent of the energy content and value of the PDF.

5. The specific methane generation rate was found to be 0.27 m^3 (STP)/kg COD removed and represents approximately 77 percent of the theoretical yield; this rate is somewhat lower than measured with the WETOX^R waste and can be explained by several factors.

6. The biogas produced was a high-quality fuel gas. In full scale, this gas would be suitable for thermal drying of PDF, process steam generation and possibly electrical generation in a spark ignition engine gen-set or gas turbine driven gen-set.

7. Because of the low sulfur content of the pressate, the BVF effluent and biogas contained relatively low concentrations of hydrogen sulfide. The sulfide levels in the biogas are sufficiently low that no handling, direct conversion (i.e., without treatment) or environmental problems are anticipated through its use. Since the BVF effluent will be aerobically polished and will thus eliminate any sulfide, its sulfide content is of no concern here.

8. The nitrogen balance around the BVF suggests that the biogas contains of the order of 1 percent ammonia; however, this component was not measured during routine gas analyses.

9. As with the WETOX^R waste, there was no evidence of biological toxicity in the BVF; moreover, none is anticipated unless the pressate characteristics change markedly from the WETOX^R waste studied previously or wet-carb waste studied here.

10. The BOD/N/P ratio for this wet-carb waste was found to be approximately 500/5/1.5; therefore no macronutrient addition is anticipated in full scale. Because of the nature of this waste and from the results of this study, it is also believed there are adequate micronutrients present.

11. The suspended solids mass balance revealed there was no suspended solids destruction in the reactor. This result was difficult to accept at first, based on experience with other wastes and results from other researchers. However, it is now believed the above observation may be accurate, and that the wet-carb pressate contains SS high in carbon content and/or lignin which is largely refractory.

12. Preliminary projections for full-scale indicate that sludge wasting from the BVF will be required after 1.5 to 2 years of operation and thereafter on an intermittently continuous basis.

13. The results of this study and experience suggest that this waste, because of its low TKN and ammonia levels, is only capable of generating 300-400 mg/L of alkalinity; this level will almost certainly be inadequate to maintain a suitable pH in the reactor, at all times. Therefore it is concluded that chemical addition for pH control will be a continuous requirement for this or similar wastes, in full scale. This was not the case with the WETOX^{R} pressate which came from a peat source having a higher nitrogen content and thus it had higher TKN and ammonia levels.

14. The high nitrate concentrations from treatment of this and similar wastes can be a cause of concern if the effluent enters relatively small streams or aquifers used for drinking purposes.

15. Discharge of the nitrified effluent to an excavated bog area should be considered.

16. The estimated capital cost for a full-scale BVF for the proposed Barrington, N.S. and Milford, Maine peat projects is approximately $670 000 and $5 200 000, respectively; the projected O and M costs are $215 000 and $447 000, respectively.

    The Maine project is 33 times larger in size, and it will benefit, significantly, (in terms of treatment costs) from economy of scale, as these above costs indicate.

1.1.2 Nitrification Study Conclusions

1. Nearly complete nitrification of the BVF anaerobic effluent was achieved using the activated sludge process at 1 and 2 days HRT operation and temperatures of 22, 17, and 15°C.

2. Average NH_3-N effluent concentrations ranged from 1.6 to 2.6 mg/L at 2 days HRT and from 1.5 to 3.3 at 1 day HRT for the temperature range (15 to 22°C) investigated. Once the nitrifying population was acclimatized to the wastewater at the operating temperature, a consistently high degree of nitrogen transformation was achieved. Ammonia nitrogen conversions were similar at 1 and 2 days HRT; percent NH_3-N removals ranged from 95.5 to 97.8 percent during those periods of efficient nitrification.

3. Mass balance calculations for influent and effluent nitrogen parameters indicated a very good check, with only approximately 10 percent of influent nitrogen (on average) unaccounted for. Denitrification during solids settling

prior to recycle to the aeration cells was found to be insignificant. Thus the majority of this apparent nitrogen loss is believed to be the result of air stripping of NH_3-N.

4. Although nearly complete nitrification was found to occur at average temperatures as low as 15°C, failure to maintain an SRT above 20 days (SRT was 18 days at 17°C and 7 days at 15°C for model #2) would be expected to result in ultimate cessation of the nitrification process. Excessive solids loss in the effluent due to poor settling characteristics was found to be the principal cause of reduced SRT in phases 2 and 3 for model #2.

5. Steady-state COD removals at 22°C ranged between 19 and 25 percent (25 percent average removal at 2 days HRT and 19.8 percent average removal at 1 day HRT). The high CODs and low COD removals indicated the relatively high refractory nature of the anaerobic effluent. BOD removals were, as expected, higher on average at 22°C versus 15°C. This study indicated that BOD removals at 2 days HRT exceeded 90 percent on occasion, and averaged approximately 77 percent at an operating temperature of 22°C. At 15°C, BOD removals as high as 70 percent were obtained and averaged approximately 60 percent. At 1 day HRT, average BOD removals of 66.5 percent, at 22°C, and 38.6 percent, at 15°C, were observed.

6. The potential toxicity of the aerobic effluent to fish was qualified on the basis of un-ionized NH_3-N estimates and the measured NO_2-N effluent concentrations. On the basis of un-ionized NH_3-N concentrations, there is the likelihood that the aerobic effluent would periodically exceed a 4 day

LC_{50} at full concentration. In terms of potential NO_2-N toxicity, average effluent concentrations ranged from 1.5 to 3.3 mg/L for both activated sludge systems. At these levels, the full-strength aerobic effluent could be expected to routinely fail the 4 day LC_{50} test; thus there is more concern for nitrite rather than ammonia toxicity.

1.2 Recommendations

The major recommendation from this study is that:

1. A large pilot or demonstration scale study should be undertaken to verify the results of this work and to establish firm full-scale design criteria for both the anaerobic and aerobic stages of treatment.

2.0 INTRODUCTION

The use of peat as an alternative fuel source has gained an increased interest in the past few years. However, one of the major technical and economic hurdles associated with the utilization of peat as an energy source is the reduction of its water content.

A moisture content of 50 percent or less is required for efficient, direct combustion. Following heat treatment, the peat can be dewatered to 50 percent solids with conventional dewatering equipment.

Heat treatment is accomplished by either of two processes, those being wet oxidation and wet carbonization. The major disadvantage of either process is that upon dewatering, a strong waste effluent is produced due to the chemical changes and dissolution of substances during the heat treatment process.

A recent ADI study on anaerobic treatment of ORF WET-OX^{R} peat pressate using both the ADI-BVF and NRC's DFF showed that this waste was very amenable to anaerobic treatment, with typical COD/BOD removals being in the range of 60-70/80-90 percent.[1] However, high ammonia levels in the anaerobic effluents ensured that these would be toxic to fish. A simple, ten-day aerated pond was operated using BVF effluent. While BOD and ammonia removals were quite high, the aerobic effluent still contained ammonia levels high enough to be toxic to fish.

In this study, it was proposed to conduct a similar study to verify the anaerobic treatability of wet carbonization peat pressate using the ADI-BVF. In order to further investigate the increased removal of ammonia to produce a nontoxic effluent, two nitrification-activated sludge systems, at two different HRTs, and three different temperatures, were studied.

3.0 OBJECTIVES

The objectives of this study are listed below in point form:

1. To verify the treatability of wet carbonization peat pressate using the ADI-BVF;

2. To assess biogas production as well as the performance of the BVF in terms of BOD/COD removal, as a function of organic loading;

3. To assess the impact of aerobic activated sludge systems, operated at two different HRTs and at three temperatures, on the removal of BOD and ammonia nitrogen from the BVF effluent.

4. To develop preliminary, full-scale BVF design criteria and specific methane generation rates;

5. To develop preliminary capital and annual operating and maintenance costs for a full-scale BVF.

The above objectives were met through a bench-scale study which lasted approximately twenty weeks and thirteen weeks for the BVF and nitrification activated sludge systems, respectively.

During the laboratory study, the organic loading to the BVF was gradually increased and its performance assessed in an effort to identify an optimum design loading and to determine biogas quantities and quality. This preliminary design loading and

biogas data were then used to develop the capital and operating costs of a full-scale BVF, and to project the quantities of methane recovered in treatment.

During the aerobic portion of the study, two separate nitrification-activated sludge systems (HRT = 1 and 2 days) were operated at three temperatures (22, 17, and 15°C) to assess nitrification and BOD removal performance. It was anticipated that solids retention times (SRT) in excess of 20 days could be established and maintained in the activated sludge system throughout the study.

4.0 CHARACTERISTICS OF WET CARBONIZATION PEAT PRESSATE

4.1 General

The peat pressate used in this study was produced using a pilot wet carbonization reactor. Details of the processing conditions are given in Appendix A. The raw peat was obtained from two bogs, Sunkhaze and Chemo, near Milford, Maine. Table 4.1 shows raw peat slurry and peat-derived fuel characteristics for each bog.

TABLE 4.1 RAW PEAT SLURRY AND PEAT-DERIVED FUEL CHARACTERISTICS*

Parameter	Raw Peat Slurry		Peat-Derived Fuel	
	Sunkhaze	Chemo	Sunkhaze	Chemo
Humification (von Post)	H3-H4	H6-H7	-	-
Moisture as received (%)	92.24	95.33	42.78	41.57
Ash (%)	1.80	1.14	1.68	1.26
Volatiles (%)	68.15	68.88	60.46	59.98
Fixed Carbon (%)	30.05	29.98	37.86	38.75
Carbon (%)	54.20	52.88	64.03	63.36
Hydrogen (%)	5.60	5.61	5.55	5.46
Sulfur (%)	0.11	0.11	0.16	0.12
Nitrogen (%)	0.92	0.74	1.17	0.92
Oxygen (%)	37.41	39.52	27.38	28.87
Higher Heating Value (MJ/kg)	21.1	20.3	25.6	24.9

* All analyses on % dry weight basis

4.2 Wet Carbonization Peat Pressate

The wet carbonization peat pressate was obtained from the Institute of Gas Technology, Chicago, ILL., U.S.A. The pressate was received as a one time shipment and was shipped to ADI's laboratory in Fredericton in two 45-gallon, plastic-lined, metal drums. The contents of each drum were then thoroughly mixed and transferred into 5-gallon plastic containers. The pressate was then frozen in these containers until it was needed as feed for the BVF.

Following receipt of the pressate, a complete analysis, including heavy metals, was performed on each barrel. Table 4.2 presents these results.

TABLE 4.2 ANALYSIS OF RAW WET-CARB PEAT PRESSATE

Parameter	Barrel #1 - Chemo	Barrel #2 - Sunkhaze
BODT	5 355	5 310
CODT	14 250	13 617
CODS	12 800	12 100
TKN	190	166
NH_3-N	56.9	41.9
Total Phosphorus	15.4	13.8
Total Sulfur	173	114
SO_4	47	63.7
Sulfide (Total)	1.6	3.1
Sulfide (Soluble)	1.6	3.1
TS	9 298	8 853
TVS	8 720	8 306
SS	1 046	734
VSS	1 004	707
VA	1 398	1 333
ALK	0	0
pH (units)	3.4	3.5
Ca	103	85
Cd	0.09	0.06
Co	< 0.02	< 0.02
Cr	< 0.02	< 0.02
Cu	0.12	0.12
Fe	85.1	72.3
Hg (ug/L)	< 0.2	< 0.2
K	4.92	4.07
Mg	31.6	27.0
Na	4.20	4.70
Ni	0.12	0.14
Pb	< 0.02	< 0.02
Se	< 0.10	< 0.10
Zn	10.5	8.09

Notes:

1. All results in mg/L unless otherwise indicated.
2. All results are averages of at least two analyses (Barrel #2 average of three analyses).

5.0 BENCH-SCALE MODELS

Two bench-scale bulk volume fermenters (BVF) were operated in parallel to treat the wet carbonization peat pressate. BVF #1 was used to assess the treatability of the waste and was monitored intensively (see Table 6.4) while BVF #2 was used mainly for the production of additional anaerobic effluent for use in the aerobic portion of the study and was less intensively monitored (see Table 6.4). A schematic of the BVF #1 treatment system is shown in Figure 5.1.

The effluent from both BVFs was used as feed for the two nitrification-activated sludge models, model #1 having an HRT of two days while model #2 had an HRT of one day. A schematic of the nitrification system is shown in Figure 5.2. A brief description of each model follows.

5.1 Bulk Volume Fermenter

As was mentioned previously, two BVFs were used in this study. BVF #1, shown in section on Figure 5.3, is described in detail here. It was constructed of 140 mm inside diameter (i.d.) plexiglas tubing and had an overall length of approximately 490 mm. The liquid volume of the reactor was approximately 6.4 L. One end cover was permanently fixed to the model, while the other was removable and made liquid and gastight with suitable "O" rings and bolts. Provisions were made for a sludge and effluent recycle port, as well as a gas sampling port. The effluent port was designed such that the back pressure from the Triton gas meter would not affect the liquid volume in the reactor.

BVF #2, used mainly to produce an additional source of anaerobic effluent, consisted of a wooden rectangular box with inside dimensions being 51 x 13 x 11.5 cm. The liquid volume was approximately 7.7 L. Sludge recycle was accomplished by manually mixing the reactor contents once per day. No gas collection or effluent recycle was carried out in this model.

5.2 Feed, Recycle and Biogas Systems

In both BVFs the feed rate was controlled by a variable-speed peristaltic pump and timer. Feeds for all models were mixed while the models were being fed. The feed for both BVFs was prepared once per week and kept at room temperature (approximately 22°C) to minimize waste degradation.

Effluent recycle (intermittently continuous) in BVF #1 was accomplished by using a peristaltic pump and timer. The effluent recycle rate:feed rate ratio was set at 1:1 throughout the study.

Sludge was recycled daily in BVF #1 by manually operating a peristaltic pump until the return line was clear of sludge. This was done on a daily basis, 5 days per week.

Biogas from BVF #1 was measured, using a Triton gas volume displacement meter, collected in 8-L Tedlar (polyvinyl fluoride) gas sampling bags and analyzed to determine the specific methane generation rate. Gas production was not monitored in BVF #2.

5.3 Nitrification-Activated Sludge Models

An aerobic polishing step was included in the overall treatment train to further stabilize the BVF effluent, principally to effect ammonia nitrogen and further BOD removal. Aerobic treatment consisted of two bench-scale activated sludge reactor

systems, referred to herein as model #1 and model #2. Both systems were of similar design, each consisting of an aeration cell (plastic graduated cylinder) and effluent settling chamber (plastic container). The aeration cells were continuously mixed and aerated using an aquarium air pump and air dispersion stones. Feed was stored in a covered plastic bucket and fed to each aeration cell using a variable speed peristaltic pump. A schematic of both activated sludge reactor systems is provided in Figure 5.2.

Model #1 aeration cell had a liquid volume of 0.98 L; model #2 aeration cell had a liquid volume of 0.55 L. Model #1 is shown in section in Figure 5.4. A single timer was used to cycle the feed pump (once per hour), as well as activate a feed container mixer during the pump on cycle. The effluent settling chambers (approximate volume of 0.6 L each) captured overflow from the aeration cells and provided quiescent settling of biomass solids for subsequent recycle. Biomass solids were recycled by decanting the settling chamber supernatant on a daily basis and returning the settled solids portion to the respective aeration cell.

A temperature control system was constructed to minimize temperature fluctuations at the desired operating temperature. Temperature control consisted of a heated and continuously mixed water bath arrangement. The water bath was contained in an insulated compartment, which was used to house both aeration cells. Flow-regulated tap water was piped into the insulated compartment, and heated to the desired temperature using a Port-A-Temp temperature controller (a combined immersion-type heating element and mixer unit). Overflow from the insulated compartment entered a second uninsulated compartment containing both effluent settling chambers. Temperature corrections were made by adjusting either the tap water flow (using an inline

valve) or the heating element thermostat. Temperature was monitored using thermometers located in both aeration cells and water bath compartments.

The feed to both nitrification models was a mixture of effluents from BVFs #1 and #2; those feeds were prepared and fed on a weekly basis from effluents collected during the previous week.

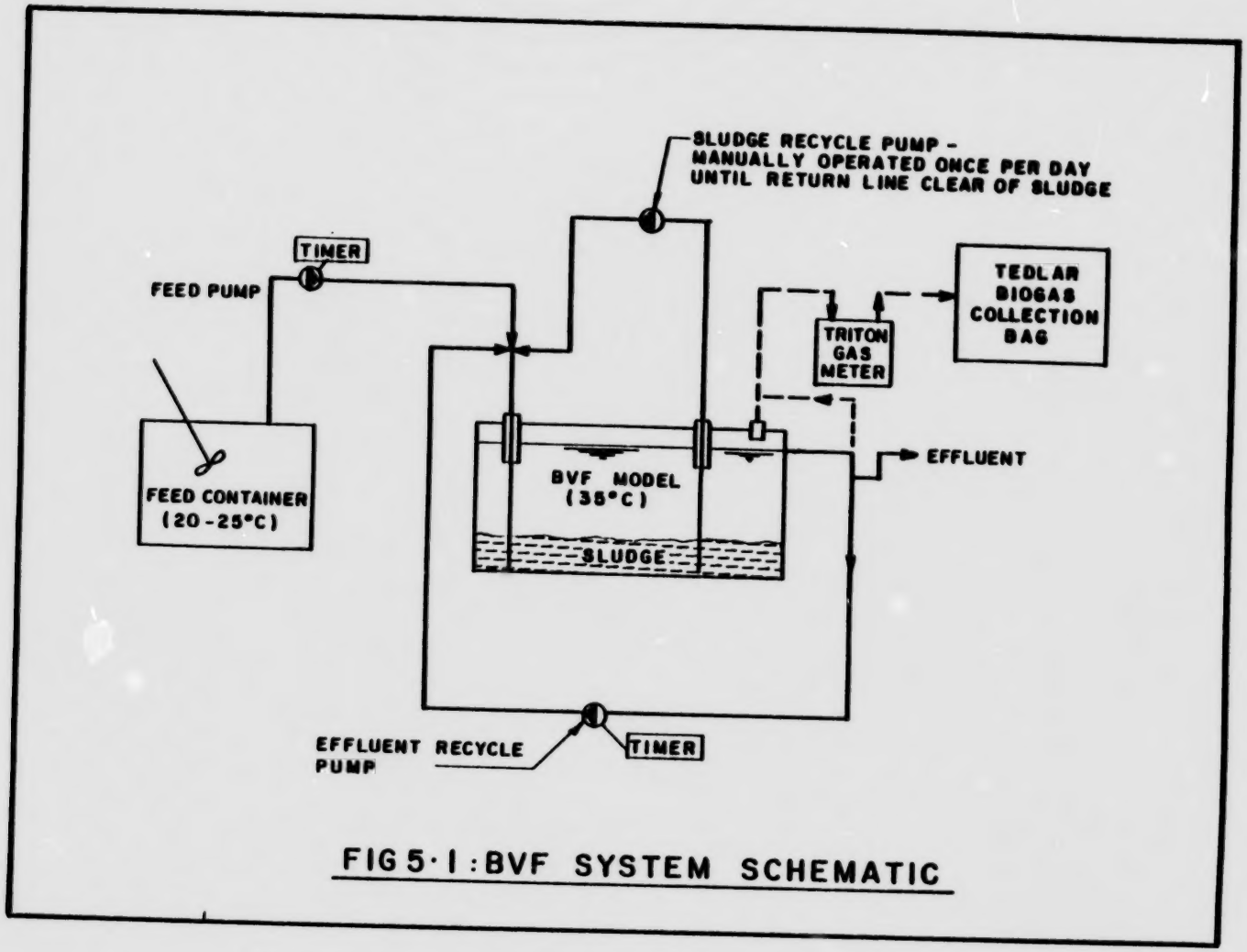


FIG 5·1 : BVF SYSTEM SCHEMATIC

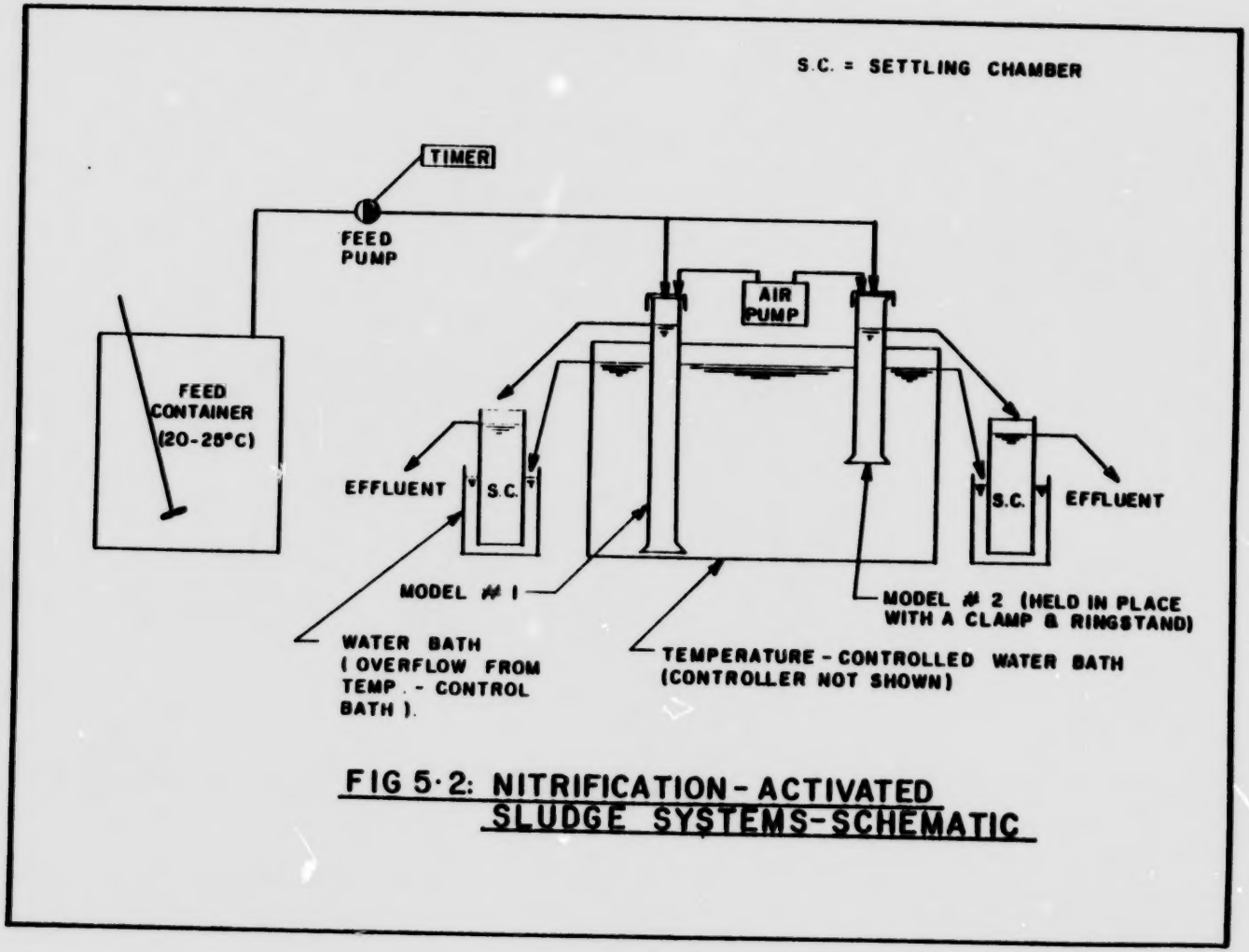


FIG 5·2: NITRIFICATION - ACTIVATED SLUDGE SYSTEMS - SCHEMATIC

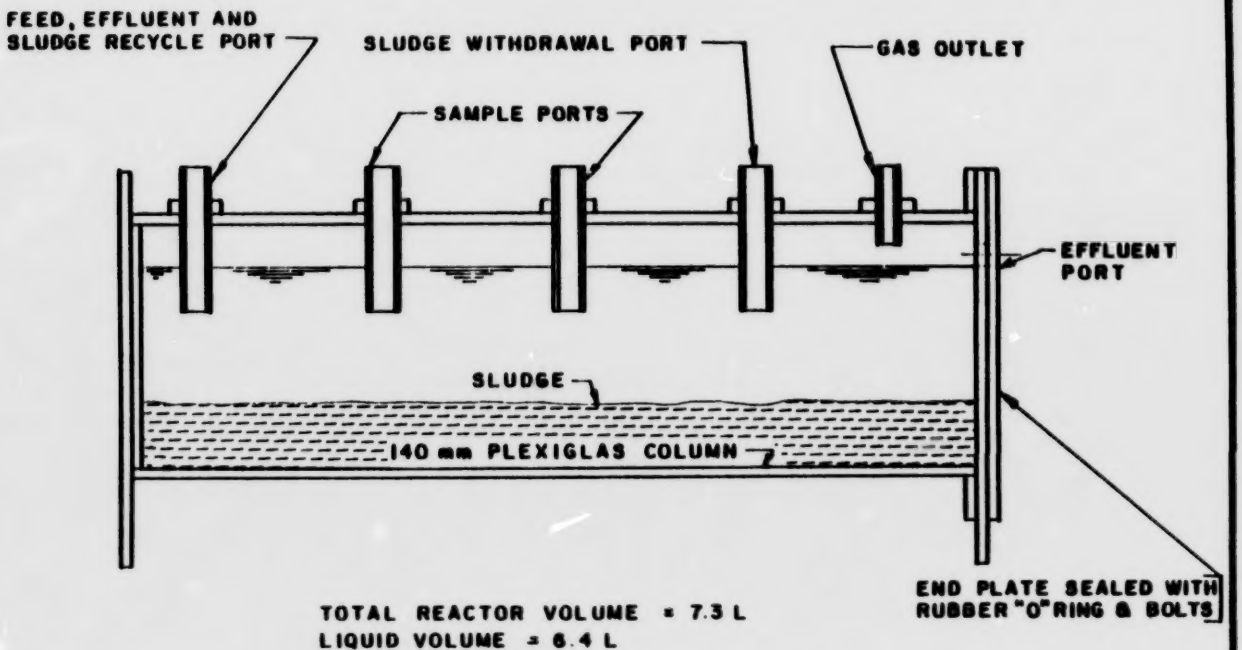


FIG 5·3 : BVF SECTION

1/3 SCALE

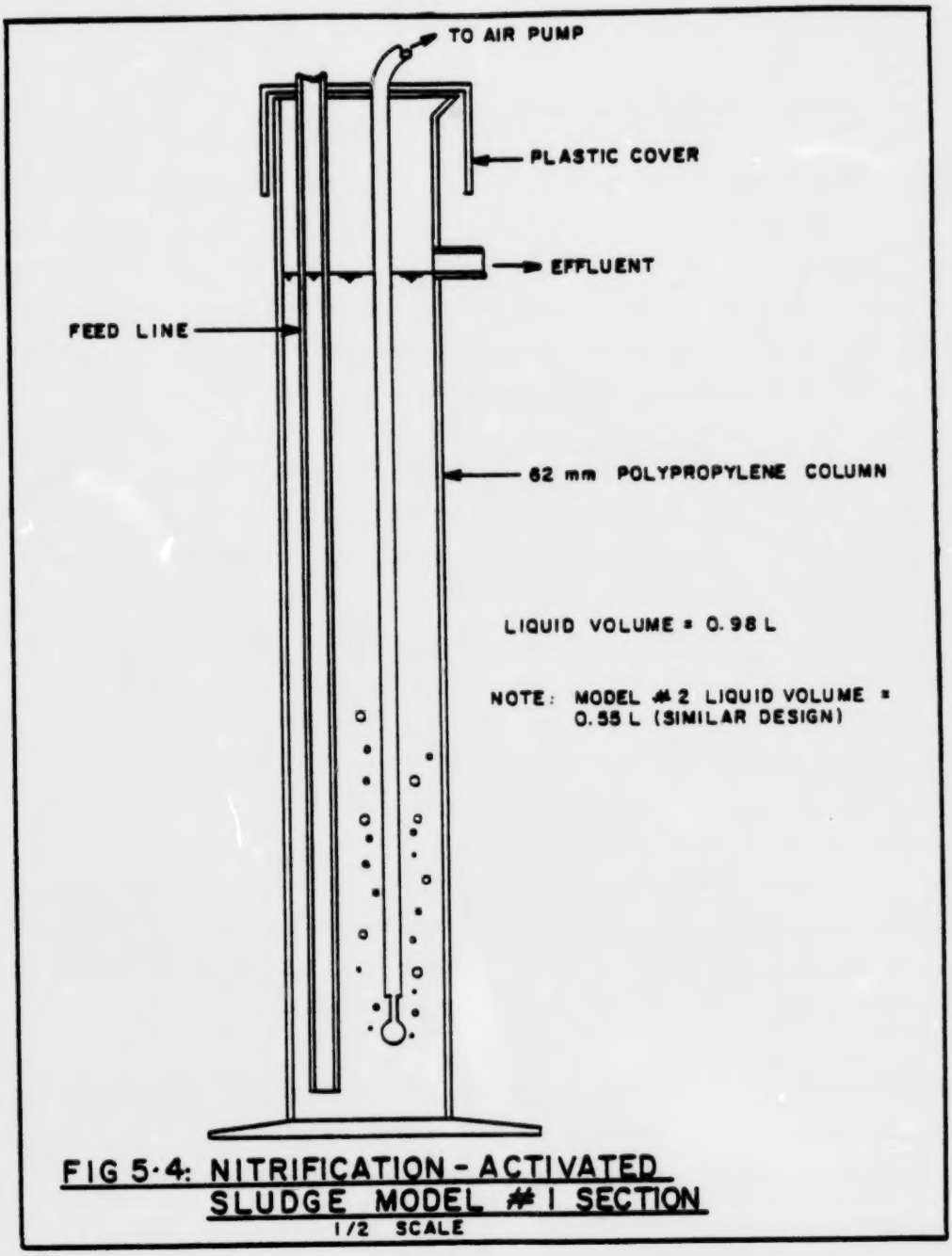


FIG 5·4: NITRIFICATION - ACTIVATED SLUDGE MODEL #1 SECTION
1/2 SCALE

6.0 MODEL OPERATIONS

6.1 Seeding and Startup - BVF

The BVF #1 was seeded with 6.3 L of peat pressate reactor sludge and supernatant from a previous study[1] on WETOX^R pressate. The TS and TVS of this mixture was 1.1 percent and 0.56 percent, respectively. The reactor was operated at 35°C, while the reactor feed was kept at room temperature to minimize waste degradation between feed preparation periods (once per week).

Due to the lack of pressate waste, the reactor was initially fed a synthetic feed mixture consisting of diluted acetic acid, NH_4Cl and KH_2PO_4 (as sources of N and P, respectively), $NaHCO_3$ and lime (for alkalinity and pH control). Following an increase in volatile acids, 0.5 L of anaerobic distillery waste processing sludge was added to the reactor (TS = 13.2 percent, TVS = 5.8 percent). A further 0.5 L of anaerobic sludge (a mixture of food processing and pulp and paper sludge) was added to the reactor (TS = 5.5 percent, TVS = 2.3 percent). Intermittently continuous effluent recycle, at an R/Q of 1/1, and sludge recycle, done manually once per day, were introduced during this start-up period. Following seventeen days of operating on synthetic feed, the reactor was temporarily shut down while awaiting the arrival of wet-carb peat pressate.

On January 2, 1985 the reactor was restarted using wet carbonization peat pressate. This corresponded to day one of the study (reference Table 6.1). The initial feed strength was 25 percent

peat pressate waste, diluted with 75 percent tap water. This was gradually increased, in 25 percent increments, to 100 percent strength on day 28. As was the case during the acclimation period, effluent and sludge recycle were accomplished at the rates described previously. The initial BOD/N/P was maintained at 250/5/1, assuming that no N and P were in the raw waste. The addition of NH_4Cl and KH_2PO_4 was stopped, on day 28, following receipt of a complete analysis of the raw waste which showed adequate levels of N and P for anaerobic treatment (BOD/N/P = approximately 500/5/1). The initial $NaHCO_3$ dosage was set at 3 g/L. Table 6.1 documents operational changes during the startup period (days 1-28).

6.2 BVF Operations

The treatability of the wet-carb peat pressate waste was assessed using the BVF technology. The loading to the BVF was gradually increased to 2.2 kg COD/m^3.d by increasing the feed rate. From day 28 onwards, the feed strength was kept at 100 percent. The $NaHCO_3$ dosage was reduced on day 22 to 2 g/L and was maintained at that level until day 63 when it was increased to 3 g/L to provide additional buffering for rising volatile acid levels. Falling VA levels reduced the need for increased alkalinity such that the $NaHCO_3$ dosage was reduced again on day 84 to 2 g/L. Table 6.1 documents the operational and loading changes made during the study.

On day 14, a second BVF (BVF #2) was started to provide an additional source of anaerobic effluent for use in the nitrification study. This reactor, having a liquid volume of 7.7 L, was seeded with 1.5 L of anaerobic municipal digester sludge (TS = 3.6 percent, TVS = 2.0 percent) and was topped up with a mixture of effluent from BVF #1 and from two anaerobic dairy waste models. The operation of this BVF parallelled that of BVF #1 in

terms of waste strength, loading and detention time. This reactor was also operated at 35°C. Sludge recycle in this BVF consisted of daily mixing the reactor contents five days per week; no provision was made for effluent recycle. Monitoring of this model was less extensive than that for BVF #1. Table 6.3 documents the analytical testing frequency.

6.3 Seeding and Startup of Nitrification Models

An initial, single aeration cell (volume 1.7 L) was started using aerobic mixed liquor obtained from the aeration basin of the Fredericton Area Pollution Control Commission (FAPCC) sewage treatment plant. This seed material was known to contain a healthy heterotrophic bacteria population. The FAPCC plant does not incorporate the nitrification process; however, it was hoped that the mixed liquor seed contained sufficient autotrophic bacteria from which a nitrifying population could be developed.

It was intended to first develop a nitrifying population from which the nitrification portion of the study could commence. A synthetic feed was prepared to promote development of autotrophic nitrifiers. The synthetic feed consisted of sucrose (source of carbon for the heterotrophic bacteria population), ammonium chloride - NH_4Cl (source of ammonia nitrogen for the autotrophic bacteria population), potassium phosphate - KH_2PO_4 (source of phosphorus), yeast extract (source of trace nutrients), and sodium bicarbonate - $NaHCO_3$ (source of alkalinity). The aeration cell was aerated continuously and operated at a feed rate of approximately 1 L/d, producing an HRT of approximately 1.7 days. The start-up temperature was maintained at room temperature, approximately 22°C.

The synthetic feed was utilized for a 17 day period, at which time the feed was switched to a diluted peat pressate BVF effluent. The purpose of introducing the dilute BVF effluent was to allow a gradual acclimatization of the various bacterial populations to this wastewater. Initially, a 20 percent BVF effluent strength (full strength effluent diluted with tap water) was used. The strength was gradually increased over a three week period in 20 percent increments to full strength. The BVF effluent was known to contain sufficient quantities of both macro and micronutrients and alkalinity. Thus the addition of fortifying chemicals (NH_4Cl, KH_2PO_4, $NaHCO_3$, yeast extract) was no longer required and therefore stopped. The initial single aeration cell operated on full strength BVF effluent feed (HRT approximately 1.7 days) for a period of 5 days (i.e., day 39P* to 43P at which time it was decided to expand the scope of the original study and reassess the experimental approach.

The study was expanded to include investigation of the nitrification process at HRTs of 1 and 2 days, and at three temperatures within the 13 to 25°C range (approximately 22-25°C, 17-19°C, and 13-15°C). To accommodate these revised variables within the available time allotted for the study, two smaller nitrification activated sludge systems were constructed and operated simultaneously. Each new aeration cell (designated nitrification activated sludge model #1 and model #2 in this study) was started with the acclimatized mixed liquor developed using the original 1.7 L aeration cell. Both aeration cells were operated on a feed flow rate of approximately 0.5 L/d, providing a 2 day HRT in model #1, and a 1 day HRT in model #2.

The start-up phase was ended and the experimental phase of the nitrification study began with the commencement of the two separate activated sludge systems (day 43P). Table 6.2 summarizes the events of the seeding and start-up procedure.

---

*P designates the seeding and start-up phases only, which included days 1P through 43P.

6.4 General Operation of Nitrification Models

The nitrification-activated sludge models #1 and #2 were operated simultaneously and in parallel. Both were operated under the same environmental conditions, on the same waste substrate (a mixture of effluents from BVF #1 and #2), and at similar flow rates. The feeds were prepared on a weekly basis.

Following the initial startup phase (days 1P to 43P), the experiment proceeded from day 1 to day 81 through three distinct temperature phases. The period of operation designated for each individual phase is provided in Section 7.3. At the end of phases 1 and 2, a gradual temperature reduction of approximately 1°C per day, to the next lower operating temperature, was conducted. The analytical tests, procedures, and schedules used to monitor the performance of the nitrification-activated sludge models are outlined in Tables 6.3 and 6.4

6.5 Analyses

In order to monitor the performance of BVF #1, daily grab samples of feed and effluent were collected and combined to form 5-day composites. These samples were refrigerated at 4°C until analyzed. The composites were analyzed for COD, BOD, SS, and VSS. In addition to these analyses, total kjeldahl nitrogen (TKN), ammoniacal nitrogen (NH_3-N) and total phosphorous were determined on a bimonthly basis. Grab samples of influent and effluent were also taken twice per week and analyzed for pH, VA and alkalinity. Total sulfide samples were also analyzed weekly on the BVF effluent. A complete frequency schedule for all testing is included in Table 6.3.

As was stated previously, BVF #2 monitoring was less extensive than that for BVF #1. Grab samples of effluent were analyzed weekly for pH, VA and alkalinity, reference Table 6.3.

Biogas production in the BVF was monitored continuously using a Triton gas volume displacement meter, with samples being collected continuously and analyzed weekly for $CO_2(+H_2S)$ and O_2, using an Orsat apparatus; H_2S was analyzed separately using an MSA apparatus. The nitrogen concentration was determined by calculation based on the concentration of oxygen in the sample and the ratio of oxygen and nitrogen in air. Methane was determined by difference. The quantities of gases other than CO_2, O_2, N_2, CH_4 and H_2S were assumed to be negligible.

One shipment of two barrels of wet-carb peat pressate was received. One sample was taken from each barrel and was subjected to a more complete analysis. The results of these analyses are presented in Table 4.2.

In order to assess the performance of the two nitrification models, grab samples of influent and effluent were analyzed three times per week for the following parameters: alkalinity, COD, BOD, SS, VSS, TKN, ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N) and nitrite nitrogen (NO_2-N). The influent waste and aeration cell pHs were monitored three times per week. In addition, the MLSS and MLVSS of the two aeration cells were monitored at least once per week.

A complete list of analytical tests and procedures used in this study is furnished in Table 6.4.

TABLE 6.1 BVF #1 MODEL OPERATIONS

Date	Day	Event
85/1/2	1	Reactor started up using peat pressate waste; feed strength = 25 percent; recycle ratio (R/Q) = 1/1; sludge recycle = once per day; BOD/N/P = 250/5/1; T = 35°C; $NaHCO_3$ dosage = 3 g/L; loading = 0.24 kg COD/m^3 d; DT = 11.4 d.
85/1/11	10	Feed strength increased to 50 percent; loading = 0.44 kg COD/m^3 d; DT = 10.8 d.
85/1/22	21	Feed strength increased to 75 percent; loading = 1.14 kg COD/m^3 d; DT = 10.1 d; $NaHCO_3$ dosage reduced to 2 g/L.
85/1/29	28	Feed strength increased to 100 percent; NH_4Cl + KH_2PO_4 addition stopped; loading = 0.81 kg COD/m^3 d; DT = 16 d.
85/2/5	35	Loading = 1.48 kg COD/m^3 d; DT = 9.8 d.
85/2/12	42	Loading = 1.61 kg COD/m^3 d; DT = 9.3 d.
85/2/19	49	Loading = 1.22 kg COD/m^3 d; DT = 10.1 d.
85/2/26	56	Loading = 2.09 kg COD/m^3 d; DT = 6.7 d.
85/3/5	63	Loading = 2.56 kg COD/m^3 d; DT = 5.5 d; $NaHCO_3$ dosage increased to 3 g/L.
85/3/12	70	Loading = 2.23 kg COD/m^3 d; DT = 6.7 d.
85/3/19	77	Loading = 1.78 kg COD/m^3 d; DT = 8.3 d.
85/3/26	84	Loading = 2.22 kg COD/m^3 d; DT = 6.8 d; $NaHCO_3$ dosage reduced to 2 g/L.
85/4/2	91	Loading = 2.13 kg COD/m^3 d; DT = 6.4 d.
85/4/9	98	Loading = 2.16 kg COD/m^3 d; DT = 6.7 d; $NaHCO_3$ dosage reduced to 1.5 g/L.
85/4/16	105	Loading = 1.91 kg COD/m^3 d; DT = 6.4 d; $NaHCO_3$ dosage reduced to 1.0 g/L.

TABLE 6.1 BVF #1 MODEL OPERATIONS (continued)

Date	Day	Event
85/4/19	108	$NaHCO_3$ dosage increased to 2.0 g/L.
85/4/23	112	Loading = 2.01 kg COD/m^3 d; DT = 6.7 d; $NaHCO_3$ dosage reduced to 1.5 g/L.
85/4/30	119	Loading = 1.41 kg COD/m^3 d; DT = 6.9 d.
85/5/7	126	Loading = 1.93 kg COD/m^3 d; DT = 7.3 d.
85/5/14	133	Loading = 2.55 kg COD/m^3 d; DT = 7.4 d.
85/5/17	136	Model shut down.

TABLE 6.2 SUMMARY OF SEEDING AND START-UP EVENTS FOR NITRIFICATION-ACTIVATED SLUDGE MODELS

Date	Startup Day	Event
85/1/15	1P	First reactor started; Vol = 1.7 L; Q = 1 L/d. Semicontinuous feeding basis, continuous aeration. Feed substrate composed of sucrose, N & P (as NH_4Cl and KH_2PO_4), $NaHCO_3$, and yeast extract; solids recycled to aeration cell on a once per day basis; temperature of operation 23°C.
85/1/31	17P	Feed changed to 20 percent strength peat pressate BVF effluent (i.e., 20% full strength effluent, 80% tap water).
85/2/6	23P	Feed strength increased to 40 percent.
85/2/12	29P	Feed strength increased to 60 percent.
85/1/15	32P	Feed strength increased to 80 percent.
85/2/22	39P	Feed strength increased to 100 percent BVF effluent.
85/2/26	43P*	Initial aeration cell contents used to start two new smaller activated sludge systems; volumes = 0.98 L and 0.55 L; Q = 0.5 L/d. Solids recycled to aeration cell on a once per day basis. Temperature of operation approximately 23°C (average).

*Day 43P equals day 1 for the two nitrification models.

TABLE 6.3 ANALYTICAL TEST/FREQUENCY SCHEDULE

	Anaerobic				Nitrification-Activated Sludge		
Test	Influent	BVF #1 Effluent	BVF #2 Effluent	Biogas	Influent	Effluent*	Reactor
pH	2/w	2/w	1/w		3/w		5/w
Temp.		5/w				5/w	
BOD	1/w*	1/w*			3/w	3/w	
COD	1/w*	1/w*			3/w	3/w	
SS	1/w*	1/w*			3/w	3/w	
VSS	1/w*	1/w*			3/w	3/w	
VA	2/w	2/w	1/w				
ALK	2/w	2/w	1/w		3/w	3/w	
TKN	2/m*	2/m*			3/w	3/w	
NH_3-N	2/m*	2/m*			3/w	3/w	
NO_3-N					3/w	3/w	
NO_2-N					3/w	3/w	
TOT-P	2/m*	2/m*					
Sulfide	1/w	1/w					
MLSS							1/w
MLVSS							1/w
CH_4				1/w			
CO_2				1/w			
H_2S				1/w			

1/w = once per week
2/w = twice per week
3/w = three times per week
5/w = daily
2/m = twice per month
* indicates a 5-day composite (all other samples are grabs)
* indicates effluent from both reactors

TABLE 6.4 ANALYTICAL PROCEDURES

Parameter	Procedure
BOD	Standard Methods (2)
COD	Dichromate Digestion, Hach
SS	Standard Methods (2)
VSS	Standard Methods (2)
TS	Standard Methods (2)
TVS	Standard Methods (2)
TKN	Standard Methods (2)
NH_3-N	Standard Methods (2)
NO_3-N	Standard Methods (2)
NO_2-N	Standard Methods (2)
Total Phosphorus	Standard Methods (2)
Total Sulfur	TAPPI Standard Method (3)
SO_4	Standard Methods (2)
Sulphide	Standard Methods (2)
Alkalinity	Standard Methods (2)
VA	See Reference (4)
Ca	Standard Methods (2)
Cd	Atomic Absorption (AA)
Co	AA
Cr	AA
Cu	AA
Fe	AA
K	AA
Mg	AA
Na	AA
Ni	AA
Pb	AA
Se	AA
Zn	AA
Hg	Standard Methods (2)
Gas - CO_2 ($+H_2S$)	ORSAT, (see reference (5))
Gas - H_2S	MSA apparatus (Samplair Pump and H_2S tubes)

7.0 RESULTS

The performance of the BVF was monitored throughout the study as the organic loading was progressively increased. Toward the end of the study, the loading was held as constant as possible (approximately 2.1 kg COD/m^3.d) in order to produce steady-state conditions and an effluent of reasonably consistent characteristics. As stated previously, this effluent was the feed to the nitrification systems. The routine analytical tests done on each model and the frequency of testing are shown in Table 6.3 and discussed in Section 6.6.

7.1 BVF

The figures listed below present the temporal variation of the respective parameters in graphical form. These can be found at the end of Section 7. Only BVF #1 results are presented in these figures.

Figure 7.1 - COD and BOD Concentrations
Figure 7.2 - COD and BOD Loadings
Figure 7.3 - COD and BOD Removals
Figure 7.4 - SS and VSS Concentrations
Figure 7.5 - SS and VSS Loadings
Figure 7.6 - SS and VSS Removals
Figure 7.7 - VA Concentrations, Influent and Effluent
Figure 7.8 - pH Values, Influent and Effluent
Figure 7.9 - Alkalinity Concentrations, Influent and Effluent

Tables 7.1, 7.2 and 7.3 present nitrogen (TKN and NH_3-N) and total phosphorus, total sulfide and specific methane generation and gas composition data from the BVF #1 operations, respectively. Table 7.4 presents pH, VA and alkalinity data for BVF #2. These tables are located at the rear of this section.

Results indicate that COD/BOD removals in the range of 60 to 70 percent/80 to 90 percent can be obtained in the BVF. Average SS removal for the study was approximately 60 percent.

The effluent VA level remained below 900 mg/L throughout the study (see Section 8.1 and Table 8.1 for more discussion and data on VA levels in the reactor). Due to rising VA levels and decreasing pH in the effluent, the $NaHCO_3$ dosage was increased on day 63 to 3 g/L to provide an increased buffering capacity in the reactor. The effluent VA concentration continued to rise to 870 mg/L on day 69, and then gradually decreased to 400-500 mg/L towards the end of the study. Correspondingly, the pH in the effluent increased from a low of 6.7 on day 65 to approximately 7.4 on day 76. On day 84, the $NaHCO_3$ dosage was reduced from 3 g/L to 2 g/L in an effort to minimize the amount of chemical added for pH and alkalinity control. During this period, the pH averaged 7.0 in the effluent. A further reduction to 1 g/L on day 105 resulted in a decrease in pH to 6.8. The dosage was then increased to 1.5 g/L on day 112 and remained at that level until the termination of the study.

The specific methane generation rate averaged approximately 0.27 m^3 CH_4 (STP)/kg COD destroyed which is 77 percent of the theoretical value of 0.35 m^3 CH_4 (STP)/kg COD destroyed. The methane content in the biogas varied from 56 percent to 81 percent throughout the study, with the average being approximately 65 percent.

TABLE 7.1 BVF #1 TKN, NH_3-N, TOTAL P DATA

Date	Day	TKN Inf	TKN Eff	NH_3-N Inf	NH_3-N Eff	Total P Inf	Total P Eff
85/1/29-2/4	28-34	184	138	51.5	73.7	18.3	19.6
85/2/12-18	42-48	195	147	39.6	66.1	17.2	16.2
85/2/26-3/4	56-62	182	153	48.5	72.6	16.8	18.3
85/3/12-18	70-76	193	170	45.0	59.8	17.5	18.6
85/3/26-4/1	84-90	193	161	43.1	69.5	13.3	16.7
85/4/9-15	98-104	185	183	55.2	80.8	11.2	14.0
85/4/23-29	112-118	170	165	37.4	69.5	13.9	15.6
85/5/7-10	126-132	202	163	31.9	65.7	14.2	16.6
Average (S.D.)		188 (9.8)	160 (14.0)	44.0 (7.7)	69.7 (6.3)	15.3 (2.5)	16.9 (1.8)

Note: 1. S.D. = standard deviation

2. Units in mg/L

TABLE 7.2 BVF #1 TOTAL SULFIDE DATA

Date	Day	Influent	Effluent
85/2/14	44	24	10
85/2/21	51	0	0
85/3/5	63	0	3
85/3/11	69	0	6
85/3/14	72	0	2
85/3/22	80	0	2
85/4/1	90	0	0.5
85/4/9	98	0	3.9
85/4/16	105	0	4.3
85/4/19	108	0	8.3
85/4/25	114	3.7	6.3
85/5/14	133	0	0
85/5/16	135	0	0

Units in mg/L

TABLE 7.3 GAS COMPOSITION DATA

Date	Day	% CH_4	% CO_2	% O_2	% N_2	H_2S (ppm)	Spec. CH_4* Gen. Rate COD/BOD
85/1/7	6	81.4	15.8	0.6	2.2	104	0.39/
85/1/15	14	73.9	24.2	0.4	1.5	90	0.25/
85/1/22	21	72.7	25.4	0.4	1.5	47	0.25/
85/1/28	27	65.3	32.8	0.4	1.5	49	0.15/0.42
85/2/1	31	62.6	35.5	0.4	1.5	44	0.29/0.65
85/2/11	41	62.2	34.0	0.8	3.0	0	0.22/0.47
85/2/19	49	61.5	37.1	0.3	1.1	34	0.24/0.59
85/3/1	59	60.3	37.8	0.4	1.5	35	0.29/0.55
85/3/11	69	63.8	34.8	0.3	1.1	34	0.29/0.67
85/3/19	77	66.2	31.9	0.4	1.5	34	0.27/0.67
85/3/26	84	65.7	32.4	0.4	1.5	0	0.25/0.59
85/4/2	91	61.7	36.9	0.3	1.1	0	0.23/0.52
85/4/9	98	60.5	39.0	0.1	0.4	0	0.29/0.82
85/4/16	105	60.5	38.5	0.2	0.8	0	0.28/0.55
85/4/23	112	60.6	38.4	0.2	0.8	0	0.30/0.52
85/4/30	119	60.7	35.5	0.8	3.0	0	0.25/0.56
85/5/7	126	65.6	34.5	0.0	0.0	0	0.35/0.51
85/5/14	133	56.3	35.1	1.8	6.8	0	0.18/0.39
						Average (S.D.)	0.27/0.56 (0.06)(0.11)

Note: 1. Units are $\frac{m^3\ CH_4\ (STP)}{kg\ COD/BOD\ removed}$

2. S.D. - Standard Deviation

3. Figures are percent by volume except H_2S figures which are ppm

TABLE 7.4 BVF #2: EFFLUENT pH, VA AND ALK

Date	Day	pH	VA	ALK
85/1/21	20	8.5	170	3500
85/1/28	27	7.5	290	1910
85/2/4	34	7.9	473	1900
85/2/11	41	7.6	375	1682
85/2/18	48	7.2	585	1450
85/2/25	55	7.0	580	1340
85/3/4	62	7.3	668	1400
85/3/11	69	7.7	660	1800
85/3/18	76	7.8	675	2000
85/3/25	83	7.4	690	2050
85/4/1	90	7.4	600	1800
85/4/8	97	7.4	570	1700
85/4/15	104	7.6	450	1500
85/4/22	111	7.5	480	1300
85/4/29	118	7.3	464	1053
85/5/6	125	7.6	682	1364
85/5/13	132	7.4	527	1167

Units in mg/L, except pH

7.2 Operations Data: Nitrification-Activated Sludge Models #1 and #2

The nitrification study was conducted at three temperatures and lasted a total of 81 days. The three temperatures for each nitrification-activated sludge model and the duration each was studied are provided in Table 7.5. The complete operations data for both models are also summarized in this table. The operations data are expressed in terms of average values for each temperature. Detailed experimental data for each day of analysis is provided in Appendix C, Tables C.1, C.2, C.3 and C.4.

The TKN, NH_3-N, COD, and BOD loadings as determined for each day of analysis (see Appendix C, Tables C.3 and C.4) are shown graphically in Figures 7.10 and 7.11.

7.3 Nitrogen Data: Nitrification-Activated Sludge Models #1 and #2

A summary of influent nitrogen data for the nitrification-activated sludge models is given in Table 7.6. This data represents the average nitrogen concentrations obtained for each parameter for the duration of each temperature phase. The detailed data from which these values were determined is provided in Appendix D, Tables D.1 and D.2.

TABLE 7.5 SUMMARY OF OPERATIONS DATA: NITRIFICATION-ACTIVATED SLUDGE MODELS #1 AND #2

Phase	Day	Duration (days)	Temp. (°C)	Q (L/d)	HRT (days)	SRT (days)	MLVSS (mg/L)	Loadings (kg/kg MLVSS.d) TKN	NH_3-N	COD	BOD (F/M)
Model #1											
1	1-25	25	22	0.50	2.02	54	2490	0.028	0.010	0.950	0.103
2	26-60	35	17	0.49	2.02	29	1960	0.036	0.015	1.150	0.087
3	61-81	21	15	0.48	2.06	25	2910	0.022	0.009	0.745	0.050
Model #2											
1	1-25	25	22	0.52	1.07	27	2450	0.053	0.019	1.811	0.199
2	26-60	35	17	0.53	1.06	18	2480	0.056	0.024	1.790	0.135
3	61-81	21	15	0.48	1.18	7	2570	0.045	0.019	1.517	0.104

TABLE 7.6 SUMMARY OF INFLUENT NITROGEN DATA: NITRIFICATION-ACTIVATED SLUDGE MODELS #1 AND #2

Phase		Influent (mg/L) TKN	NH_3-N	NO_3-N	NO_2-N
1		137	48.5	2.1	< 0.1
	(SD)	(28)	(9.1)	(0.4)	(0)
2		146	61.5	3.6	< 0.1
	(SD)	(14)	(3.3)	(0.9)	(0)
3		131	56.4	3.0	< 0.1
	(SD)	(17)	(6.8)	(0.3)	(0)

The nitrogen effluent results for models #1 and #2 are also provided in Appendix D, Tables D.1 and D.2 respectively. A graphical representation of key influent and effluent nitrogen parameters is given in Figure 7.12 (model #1) and Figure 7.13 (model #2).

Fluctuations in the effluent nitrogen data, particularly NH_3-N results, clearly indicate that high levels of nitrification were not achieved for the entire duration of each operating phase. For each phase, portions of the nitrogen data (for both influent

and effluent data) were excluded in the overall determination of achievable nitrification efficiency. These data were excluded from analysis here only during periods when biological and operational problems were experienced (i.e., during initial development and acclimatization of the nitrifying population, plugged feed lines, blocked aeration lines, acclimatization of nitrifiers during temperature transitions). The experimental days for which influent and effluent nitrogen data were acceptable for each operating phase are listed below.

Phase	Model #1	Model #2
1	day 11 to 25	day 16 to 25, excluding day 21.
2	day 44 to 60	day 37 to 60
3	day 63 to 72	day 67 to 81

The influent and effluent nitrogen data for the above time periods is presented in Tables 7.7 and 7.8 for models #1 and #2 respectively; these data are summarized in Table 7.9.

Effluent Nitrogen data during the initial stages of phase 1 for both model #1 and #2, indicated that incomplete nitrification was occurring. These results were attributed to insufficient and unacclimatized nitrifying populations and a few operational problems which caused upsets to the activated sludge system. One such upset was created when the air supply to both models was inadvertently shut off for a 24 hour period. Analysis following the upset revealed an immediate increase in NH_3-N and a decrease in NO_3-N concentrations, indicating a ceasation of both the Nitrosomonoas and Nitrobacter nitrifying populations. However, both models #1 and #2 were able to recover following a reintroduction of air.

As in phase 1, effluent nitrogen data for both models #1 and #2 during the initial stages of phase 2 represented incomplete nitrification; these results were attributed to stress on the nitrifiers from the temperature transition (22 to 17°C), as well as an operations problem (the air supply was again inadvertently shut off for an extended period). Both models again displayed an ability to recover quickly from this type of upset.

Phase 3 Nitrogen data selected for model #1 consisted of data from the first half of this period. The nitrifiers in model #1 appeared to acclimatize more rapidly to the second temperature transition (17 to 15°C). A modest increase in NH_3-N concentrations was observed, but for a short duration. The smaller 2 degree temperature transition was apparently less stressful to the nitrifying population than the 5 degree transition occurring from phase 1 to phase 2. However, the poor nitrification results obtained during the later stages of phase 3 signified a failure condition. An explanation for this trend is not obvious, although two possibilities are:

1. A toxic condition resulting from possible ammonia and nitrous acid accumulations; and

2. A reduced nitrifying population resulting from nitrifier wash out occurring during phase 3 (could have been brought about a toxic condition).

An upset of similar magnitude had previously occurred during phase 2, from which model #1 had recovered. However, in this case the experiment was terminated prior to a possible recovery.

Phase 3 nitrification data for model #2 excluded only a small portion during the initial stages of phase 3 operation. Acclimatization of the nitrifying population from 17 to 15°C would appear to have been slightly longer in comparison to model #1, a result of the smaller model #2 nitrifier mass. Unlike model #1 however, efficient nitrification was achieved and continued until termination despite a much shorter sludge age (7 days for model #2 versus 25 days for model #1). The fact that near complete nitrification was possible in model #2 at 7 days SRT, suggests that the poor nitrification obtained for model #1 during the later stages of phase 3 was more likely the result of a toxic condition.

7.4 Carbonaceous and Solids Data: Nitrification-Activated Sludge Models #1 and #2

The complete influent and effluent carbonaceous and solids (COD, BOD, SS, VSS), and pH and alkalinity data are provided in Appendix E, Tables E.1 (model #1), and Table E.2 (model #2). The average parameter values for each phase provided in these tables are summarized in Tables 7.10 and 7.11.

Influent and effluent COD, BOD, SS, and VSS are shown graphically in Figures 7.14 and 7.15 (model #1), and Figures 7.16 and 7.17 (model #2).

TABLE 7.7 SELECTED NITROGEN DATA : NITRIFICATION - ACTIVATED SLUDGE MODEL # 1

DATE	DAY	INFLUENT TKN	INFLUENT NH3-N	INFLUENT NO3-N	INFLUENT NO2-N	EFFLUENT TKN	EFFLUENT NH3-N	EFFLUENT NO3-N	EFFLUENT NO2-N
		(mg/L)							
85 2 26	1				*				
85 2 27	2								
85 3 1	4								
85 3 4	7								
85 3 6	9								
85 3 8	11	198	49.0	2.0	0.1	65.9	1.7	51.1	1.2
85 3 11	14	141	53.0	1.5	0.1	69.6	3.1	44.0	1.1
85 3 13	16	124	53.0	2.4	0.1	61.3	2.4	46.9	1.2
85 3 15	18	142	52.5	2.1	0.1	64.7	3.6	38.7	1.3
85 3 18	21	170	57.6	2.5	0.1	71.6	3.7	48.4	1.4
85 3 20	23	151	56.5	2.7	0.1	76.4	1.3	71.8	0.6
85 3 22	25	127	58.3	2.6	0.1	71.3	0.5	71.4	0.8
AVG		150	54.3	2.3	0.1	68.7	2.3	53.2	1.1
STD DEV		24	3.1	0.4	0.0	4.7	1.1	12.2	0.3
85 3 25	28								
85 3 27	30								
85 3 29	32								
85 4 1	35								
85 4 3	37								
85 4 8	42								
85 4 10	44	135	64.7	3.6	0.1	76.7	2.7	59.7	7.2
85 4 12	46	148	58.9	4.1	0.1	72.5	1.0	64.2	0.7
85 4 15	49	132	55.1	5.8	0.1	79.7	2.3	68.5	0.9
85 4 17	51	163	65.1	4.4	0.1	78.4	1.4	85.5	0.5
85 4 19	53	147	65.9	4.3	0.1	79.8	1.8	79.8	0.8
85 4 22	56	175	59.5	3.4	0.1	91.7	1.9	77.2	1.8
85 4 24	58	162	66.9	4.0	0.1	84.8	0.7	88.2	0.9
85 4 26	60	161	62.5	3.8	0.1	81.3	1.3	90.5	0.6
AVG		153	62.3	4.2	0.1	80.6	1.6	76.7	1.7
STD DEV		14	3.9	0.7	0.0	5.3	0.6	10.7	2.1
85 4 29	63	158	64.2	3.3	0.1	81.5	2.1	79.4	1.9
85 5 1	65	144	65.7	3.5	0.1	83.0	5.9	61.5	1.3
85 5 3	67	148	61.5	3.1	0.1	79.0	0.5	72.3	0.5
85 5 6	70	133	55.1	3.2	0.1	76.9	0.8	68.5	0.8
85 5 8	72	101	48.3	3.0	0.1	83.4	3.5	65.3	0.7
85 5 10	74								
85 5 13	77								
85 5 15	79								
85 5 17	81								
AVG		137	59.0	3.2	0.1	80.8	2.6	69.4	1.0
STD DEV		20	6.4	0.2	0.0	2.5	2.0	6.1	0.5

* NO2-N values measured as < 0.1 mg/L but assumed as 0.1 for calculation purposes

TABLE 7.8 SELECTED NITROGEN DATA : NITRIFICATION - ACTIVATED SLUDGE MODEL # 2

DATE	DAY	INFLUENT TKN	INFLUENT NH3-N	INFLUENT NO3-N	INFLUENT NO2-N	EFFLUENT TKN	EFFLUENT NH3-N	EFFLUENT NO3-N	EFFLUENT NO2-N
		(mg/L)							
85 2 26	1				*				
85 2 27	2								
85 3 1	4								
85 3 4	7								
85 3 6	9								
85 3 8	11								
85 3 11	14								
85 3 13	16	124	53.0	2.4	0.1	77.0	2.7	43.5	7.1
85 3 15	18	142	52.5	2.1	0.1	69.3	5.6	43.5	4.6
85 3 18	21								
85 3 20	23	151	56.5	2.7	0.1	77.2	2.0	59.0	2.5
85 3 22	25	127	58.3	2.6	0.1	75.3	0.5	66.9	1.3
AVG		136	55.1	2.5	0.1	74.7	2.6	53.2	3.9
STD DEV		11	2.4	0.2	0.0	3.2	2.0	10.1	2.2
85 3 25	28								
85 3 27	30								
85 3 29	32								
85 4 1	35								
85 4 3	37	133	62.1	2.7	0.1	69.8	1.3	63.2	1.2
85 4 8	42	132	58.0	3.5	0.1	74.4	7.2	48.9	1.7
85 4 10	44	135	64.7	3.6	0.1	81.7	1.3	71.6	0.6
85 4 12	46	148	58.9	4.1	0.1	65.0	2.1	56.0	0.7
85 4 15	49	132	55.1	5.8	0.1	98.2	3.3	53.3	1.9
85 4 17	51	163	65.1	4.4	0.1	79.2	2.0	66.7	0.9
85 4 19	53	147	65.9	4.3	0.1	77.3	6.1	47.1	2.2
85 4 22	56	175	59.5	3.4	0.1	83.8	7.4	48.4	2.9
85 4 24	58	162	66.9	4.0	0.1	82.4	1.0	77.7	1.1
85 4 26	60	161	62.5	3.8	0.1	76.9	1.1	74.0	0.9
AVG		149	61.9	4.0	0.1	78.9	3.3	60.7	1.4
STD DEV		15	3.7	0.8	0.0	8.5	2.5	10.9	0.7
85 4 29	63								
85 5 1	65								
85 5 3	67	148	61.5	3.1	0.1	81.4	0.5	69.3	0.7
85 5 6	70	133	55.1	3.2	0.1	91.4	0.6	64.6	1.5
85 5 8	72	101	48.3	3.0	0.1	82.7	1.0	81.0	0.8
85 5 10	74	119	54.5	3.0	0.1	NA	NA	NA	NA
85 5 13	77	112	43.7	2.5	0.1	81.8	4.2	51.1	1.8
85 5 15	79	133	55.0	2.6	0.1	79.2	1.0	70.5	0.9
85 5 17	81	135	59.5	2.7	0.1	87.7	1.6	76.4	1.3
AVG		126	53.9	2.9	0.1	84.0	1.5	68.8	1.2
STD DEV		15	5.7	0.2	0.0	4.2	1.3	9.5	0.4

* NO2-N values measured as < 0.1 mg/L but assumed as 0.1 for calculation purposes

TABLE 7.9 SUMMARY OF SELECTED NITROGEN DATA:
NITRIFICATION-ACTIVATED SLUDGE MODELS #1 AND #2

MODEL #1

Phase		Influent (mg/L)				Effluent (mg/L)			
		TKN	NH_3-N	NO_3-N	NO_2-N	TKN	NH_3-N	NO_3-N	NO_2-N
1		150	54.3	2.3	<0.1	68.7	2.3	53.2	1.1
	(SD)	(24)	(3.1)	(0.4)	(0)	(4.7)	(1.1)	(12.2)	(0.3)
2		153	62.3	4.2	<0.1	80.6	1.6	76.7	1.7
	(SD)	(14)	(3.9)	(0.7)	(0)	(5.3)	(0.6)	(10.7)	(2.1)
3		137	59.0	3.2	<0.1	80.8	2.6	69.4	1.0
	(SD)	(20)	(6.4)	(0.2)	(0)	(2.5)	(2.0)	(6.1)	(0.5)

MODEL #2

1		136	55.1	2.5	<0.1	74.7	2.7	53.2	3.9
	(SD)	(11)	(2.4)	(0.2)	(0)	(3.2)	(2.0)	(10.1)	(2.2)
2		149	61.9	4.0	<0.1	78.9	3.3	60.7	1.4
	(SD)	(15)	(3.7)	(0.8)	(0)	(8.5)	(2.5)	(10.9)	(0.7)
3		126	53.9	2.9	<0.1	84.0	1.5	68.8	1.2
	(SD)	(15)	(5.7)	(0.2)	(0)	(4.2)	(1.3)	(9.5)	(0.4)

TABLE 7.10 SUMMARY OF CARBONACEOUS AND SOLIDS DATA:
NITRIFICATION-ACTIVATED SLUDGE MODEL #1

Phase		Influent (mg/L)						Effluent (mg/L)					
		pH	ALK	COD	BOD	SS	VSS	pH	ALK	COD	BOD	SS	VSS
1		7.7-	1695	4664	512	348	299	7.9-	1418	3482	101	77	64
	(SD)	8.2	(220)	(367)	(225)	(183)	(143)	8.5	(106)	(135)	(35)	(40)	(33)
2		7.9-	1818	4632	346	276	236	7.9-	1519	3832	111	112	95
	(SD)	8.3	(201)	(226)	(88)	(166)	(139)	8.6	(334)	(244)	(35)	(61)	(45)
3		7.1-	1352	4450	298	229	223	7.0-	1136	3794	122	116	113
	(SD)	8.6	(106)	(319)	(67)	(62)	(57)	7.9	(202)	(169)	(45)	(49)	(50)

TABLE 7.11 SUMMARY OF CARBONACEOUS AND SOLIDS DATA: NITRIFICATION-ACTIVATED SLUDGE MODEL #2

Phase		Influent (mg/L)						Effluent (mg/L)					
		pH	ALK	COD	BOD	SS	VSS	pH	ALK	COD	BOD	SS	VSS
1		7.7-8.2	1695	4664	512	348	299	7.9-8.5	1509	3731	147	83	74
	(SD)		(220)	(367)	(225)	(183)	(143)		(116)	(306)	(59)	(31)	(29)
2		7.9-8.3	1818	4632	346	276	236	7.9-8.3	1510	3846	161	124	99
	(SD)		(201)	(226)	(88)	(166)	(139)		(226)	(308)	(99)	(98)	(80)
3		7.1-8.6	1352	4450	298	229	223	7.0-8.2	1002	4039	188	332	307
	(SD)		(106)	(319)	(67)	(62)	(57)		(140)	(218)	(41)	(280)	(243)

7.5 Nitrogen Mass Balance Data: Nitrification-Activated Sludge Models #1 and #2

Influent and effluent nitrogen mass data were derived from the influent and effluent nitrogen concentration data (Appendix D, Tables D.1 and D.2) and the flow rate data (Appendix C, Tables C.1 and C.2). Individual mass balance tables were prepared for each nitrogen parameter monitored (TKN, NH_3-N, NO_3-N, NO_2-N) and are provided in Appendix F. Tables F.1, F.2, F.3 and F.4 include mass balance data for model #1; Tables F.5, F.6, F.7 and F.8 include mass balance data for model #2.

The specific mass balance information provided in Appendix F has been assembled in Tables 7.12 and 7.13 for models #1 and #2 respectively. A summation of mass data for each parameter monitored has been provided for each temperature phase, as well as for the entire experimental period, in the above tables.

7.6 Overall System Performance

Overall removals, from the BVF influent to the final aerobic effluent, obtained throughout the various phases of the study are shown in Table 7.14. Results indicate that for most parameters, the overall removals for the system utilizing the nitrification-activated model with the longer overall HRT were slightly higher. Typical COD/BOD removals for the two-stage system ranged from 72.6/97.6 to 74.9/98.0, for the system employing the nitrification model with the longer HRT (2 days). This compares to 70.8/96.2 to 73.1/97.1 for the system employing the nitrification model with the shorter HRT (1 day). Overall removals for both systems were also higher (as expected) at the higher aerobic system temperature of 22°C.

TABLE 7.12 NITROGEN MASS BALANCE DATA : NITRIFICATION - ACTIVATED SLUDGE MODEL # 1

DATE	DAY	INFLUENT TKN	INFLUENT NO3-N	INFLUENT NO2-N	INFLUENT SUM N	EFFLUENT TKN	EFFLUENT NO3-N	EFFLUENT NO2-N	EFFLUENT SUM N
		(g)							
85 2 26	1	NA	NA	NA	NA	NA	NA	NA	NA
85 2 27	2	0.012	.000	.000	0.013	0.007	0.005	.000	0.013
85 3 1	4	0.094	0.002	.000	0.096	0.051	0.015	0.003	0.070
85 3 4	7	0.171	0.002	.000	0.174	0.097	0.034	.000	0.131
85 3 6	9	0.141	0.002	.000	0.144	0.074	0.002	0.008	0.084
85 3 8	11	0.192	0.002	.000	0.194	0.064	0.050	0.001	0.115
85 3 11	14	0.145	0.002	.000	0.147	0.072	0.045	0.001	0.118
85 3 13	16	0.130	0.003	.000	0.133	0.064	0.049	0.001	0.115
85 3 15	18	0.173	0.003	.000	0.176	0.079	0.047	0.002	0.128
85 3 18	21	0.340	0.005	.000	0.345	0.143	0.097	0.003	0.243
85 3 20	23	0.137	0.002	.000	0.140	0.070	0.065	0.001	0.135
85 3 22	25	0.117	0.002	.000	0.119	0.066	0.066	0.001	0.132
SUM		1.654	0.025	0.001	1.680	0.787	0.476	0.021	1.284
85 3 25	28	0.186	0.003	.000	0.189	0.114	0.057	0.006	0.177
85 3 27	30	0.131	0.003	.000	0.134	0.090	0.020	0.003	0.114
85 3 29	32	0.105	0.002	.000	0.107	0.090	0.002	0.000	0.092
85 4 1	35	0.225	0.004	.000	0.229	0.147	0.013	0.007	0.167
85 4 3	37	0.140	0.003	.000	0.143	0.101	0.030	0.011	0.142
85 4 8	42	0.350	0.009	.000	0.359	0.245	0.059	0.035	0.338
85 4 10	44	0.147	0.004	.000	0.151	0.084	0.065	0.008	0.157
85 4 12	46	0.169	0.005	.000	0.174	0.083	0.073	0.001	0.157
85 4 15	49	0.187	0.008	.000	0.196	0.113	0.097	0.001	0.212
85 4 17	51	0.171	0.005	.000	0.176	0.082	0.090	0.001	0.173
85 4 19	53	0.151	0.004	.000	0.156	0.082	0.082	0.001	0.165
85 4 22	56	0.243	0.005	.000	0.248	0.127	0.107	0.003	0.237
85 4 24	58	0.151	0.004	.000	0.154	0.079	0.082	0.001	0.162
85 4 26	60	0.163	0.004	.000	0.167	0.082	0.091	0.001	0.174
SUM		2.518	0.063	0.002	2.582	1.519	0.869	0.078	2.466
85 4 29	63	0.220	0.005	.000	0.224	0.113	0.110	0.003	0.226
85 5 1	65	0.148	0.004	.000	0.151	0.085	0.063	0.001	0.149
85 5 3	67	0.138	0.003	.000	0.141	0.074	0.068	.000	0.142
85 5 6	70	0.174	0.004	.000	0.178	0.100	0.089	0.001	0.191
85 5 8	72	0.104	0.003	.000	0.107	0.086	0.067	0.001	0.154
85 5 10	74	0.121	0.003	.000	0.124	0.075	0.041	0.002	0.119
85 5 13	77	0.150	0.003	.000	0.153	0.117	0.021	0.003	0.141
85 5 15	79	0.135	0.003	.000	0.138	0.091	0.014	0.002	0.107
85 5 17	81	0.122	0.002	.000	0.125	0.086	0.015	0.003	0.104
SUM		1.311	0.030	0.001	1.341	0.827	0.490	0.017	1.334
TOTAL SUM		5.483	0.118	0.004	5.604	3.133	1.835	0.116	5.084

TABLE 7.13 NITROGEN MASS BALANCE DATA : NITRIFICATION - ACTIVATED SLUDGE MODEL # 2

DATE	DAY	INFLUENT				EFFLUENT			
		TKN	NO3-N	NO2-N	SUM N	TKN	NO3-N	NO2-N	SUM N
		(g)							
85 2 26	1	NA	NA	NA	NA	NA	NA	NA	NA
85 2 27	2	0.013	.000	.000	0.014	0.008	0.005	.000	0.013
85 3 1	4	0.101	0.002	.000	0.103	0.051	0.002	0.003	0.056
85 3 4	7	0.179	0.003	.000	0.181	0.120	0.030	.000	0.150
85 3 6	9	0.144	0.002	.000	0.146	0.102	0.002	.000	0.105
85 3 8	11	0.204	0.002	.000	0.206	0.079	0.004	0.002	0.085
85 3 11	14	0.168	0.002	.000	0.170	0.096	0.007	0.003	0.106
85 3 13	16	0.131	0.003	.000	0.134	0.082	0.046	0.008	0.135
85 3 15	18	0.180	0.003	.000	0.183	0.088	0.055	0.006	0.149
85 3 18	21	0.364	0.005	.000	0.369	0.190	0.012	0.004	0.205
85 3 20	23	0.149	0.003	.000	0.152	0.076	0.058	0.002	0.137
85 3 22	25	0.117	0.002	.000	0.119	0.069	0.062	0.001	0.132
SUM		1.751	0.026	0.001	1.778	0.962	0.282	0.029	1.274
85 3 25	28	0.196	0.003	.000	0.200	0.109	0.088	0.007	0.204
85 3 27	30	0.141	0.004	.000	0.145	0.075	0.074	0.001	0.149
85 3 29	32	0.109	0.002	.000	0.111	0.094	0.012	0.002	0.108
85 4 1	35	0.225	0.004	.000	0.229	0.115	0.067	0.005	0.187
85 4 3	37	0.156	0.003	.000	0.159	0.082	0.074	0.001	0.157
85 4 8	42	0.372	0.010	.000	0.382	0.210	0.138	0.005	0.353
85 4 10	44	0.151	0.004	.000	0.155	0.092	0.080	0.001	0.172
85 4 12	46	0.186	0.005	.000	0.192	0.082	0.071	0.001	0.153
85 4 15	49	0.199	0.009	.000	0.208	0.148	0.080	0.003	0.232
85 4 17	51	0.176	0.005	.000	0.181	0.086	0.072	0.001	0.159
85 4 19	53	0.153	0.004	.000	0.157	0.080	0.049	0.002	0.132
85 4 22	56	0.264	0.005	.000	0.270	0.127	0.073	0.004	0.204
85 4 24	58	0.165	0.004	.000	0.169	0.084	0.079	0.001	0.164
85 4 26	60	0.184	0.004	.000	0.188	0.088	0.084	0.001	0.173
SUM		2.678	0.067	0.002	2.747	1.471	1.041	0.035	2.547
85 4 29	63	0.220	0.005	.000	0.224	0.127	0.080	0.004	0.211
85 5 1	65	0.166	0.004	.000	0.170	0.108	0.049	0.003	0.160
85 5 3	67	0.144	0.003	.000	0.147	0.079	0.068	0.001	0.148
85 5 6	70	0.188	0.005	.000	0.192	0.129	0.091	0.002	0.222
85 5 8	72	0.107	0.003	.000	0.110	0.087	0.085	0.001	0.174
85 5 10	74	0.074	0.002	.000	0.076	NA	NA	NA	NA
85 5 13	77	0.163	0.004	.000	0.167	0.119	0.074	0.003	0.196
85 5 15	79	0.133	0.003	.000	0.136	0.079	0.071	0.001	0.151
85 5 17	81	0.130	0.003	.000	0.132	0.084	0.073	0.001	0.159
SUM		1.323	0.030	0.001	1.354	0.812	0.591	0.015	1.419
TOTAL SUM		5.752	0.123	0.004	5.879	3.246	1.915	0.079	5.240

TABLE 7.14 AVERAGE OVERALL REMOVALS: ANAEROBIC INFLUENT TO FINAL AEROBIC EFFLUENT

	Using BVF + 2-d HRT Aerobic - % Removal					
	COD	BOD	SS	VSS	TKN	NH_3-N
Phase 1						
Aerobic T = 22°C	74.9	98.0	91.9	92.7	63.5	94.8
Phase 2						
Aerobic T = 17°C	72.4	97.8	88.2	89.1	57.1	96.4
Phase 3						
Aerobic T = 15°C	72.6	97.6	87.8	87.0	57.0	94.1

	Using BVF + 1-d HRT Aerobic - % Removal					
	COD	BOD	SS	VSS	TKN	NH_3-N
Phase 1						
Aerobic T = 22°C	73.1	97.1	91.2	91.5	60.3	94.1
Phase 2						
Aerobic T = 17°C	72.2	96.8	86.9	88.6	58.0	92.5
Phase 3						
Aerobic T = 15°C	70.8	96.2	65.0	64.8	55.3	96.6

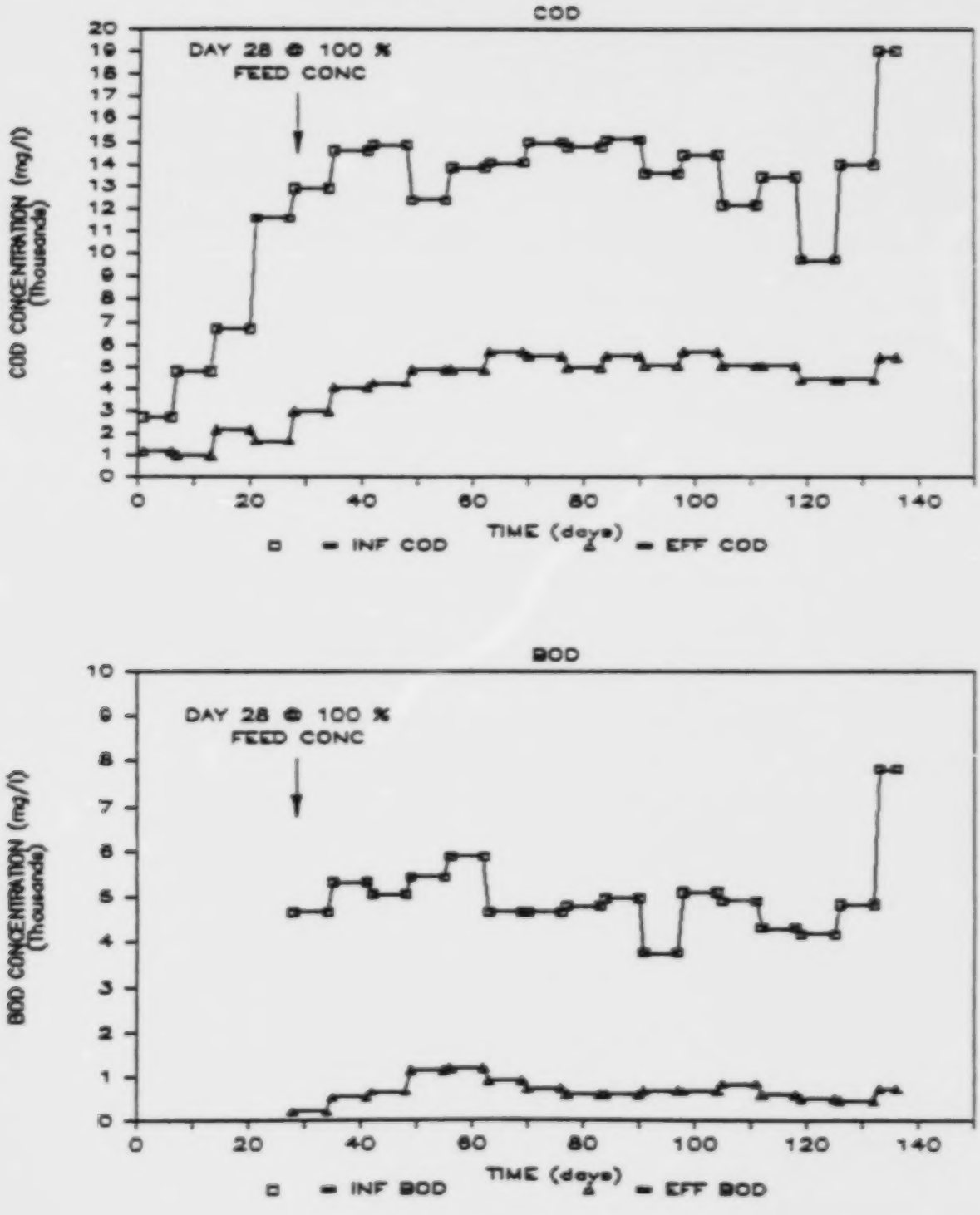
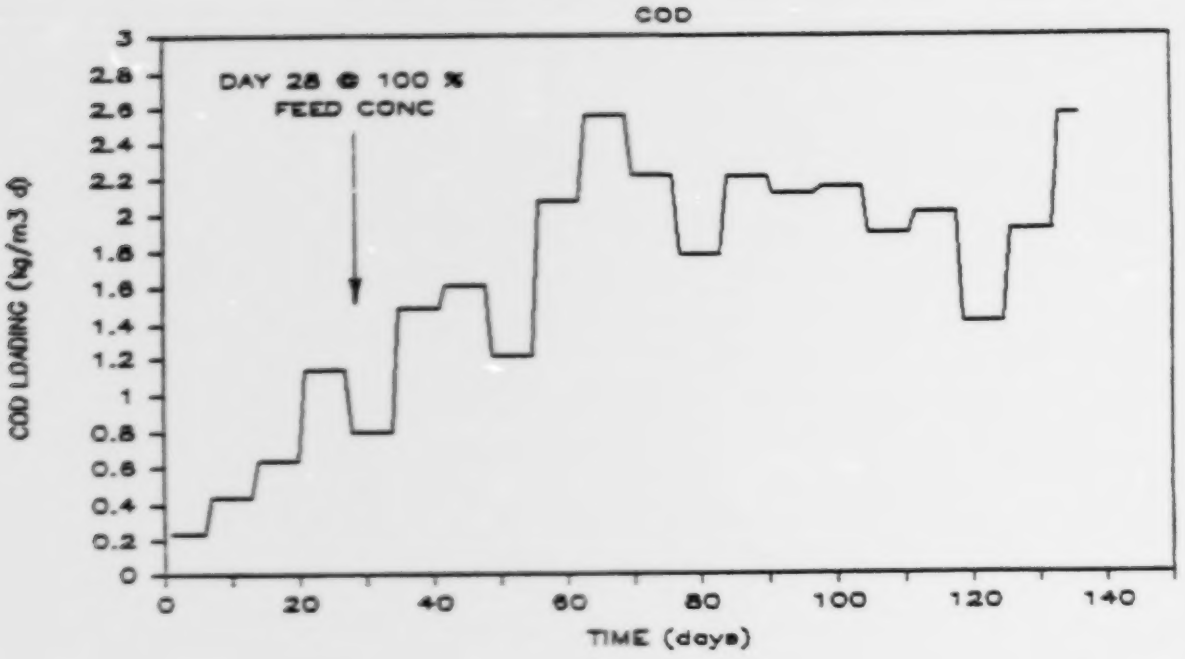


FIGURE 7.1

RVF #1 COD AND BOD CONCENTRATIONS



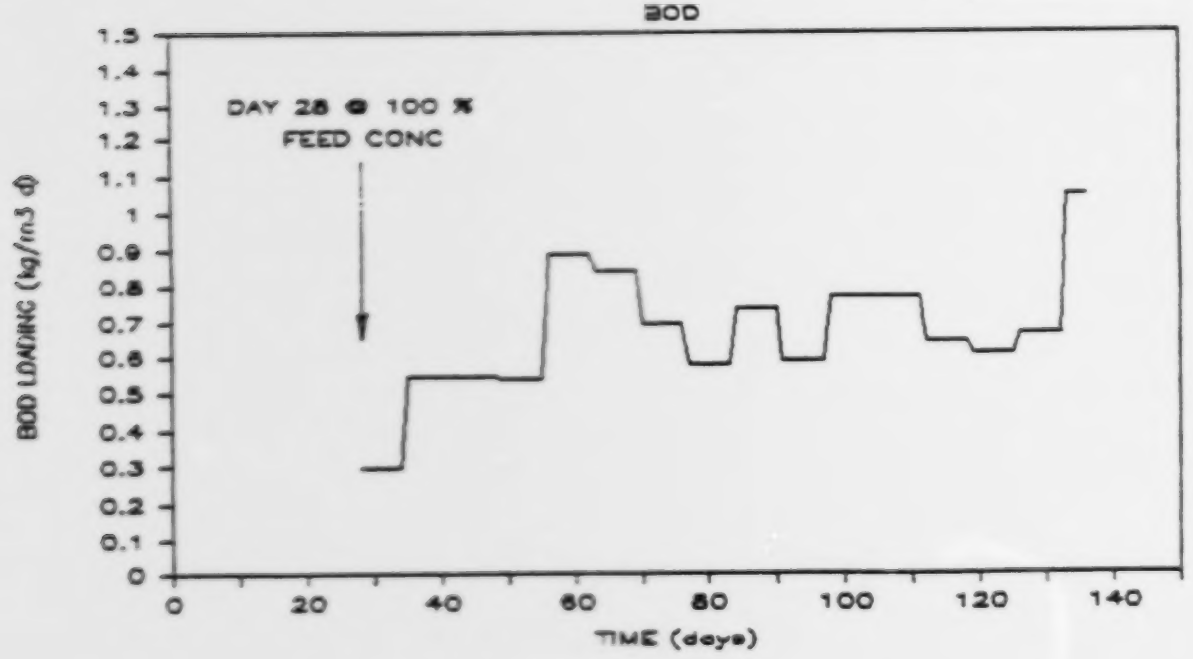


FIGURE 7.2

BVF #1 COD AND BOD LOADINGS

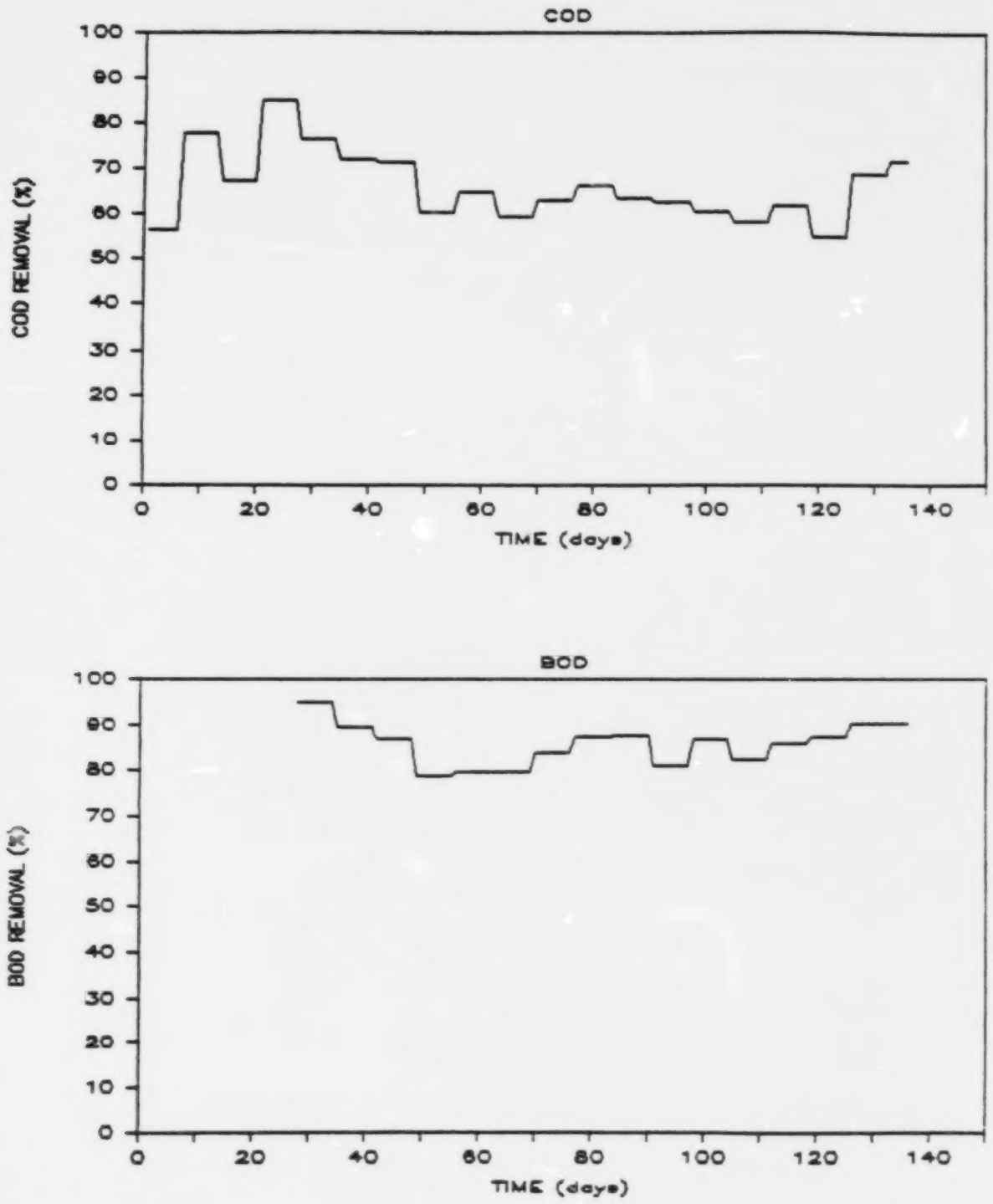


FIGURE 7.3

BVF #1 COD AND BOD REMOVALS

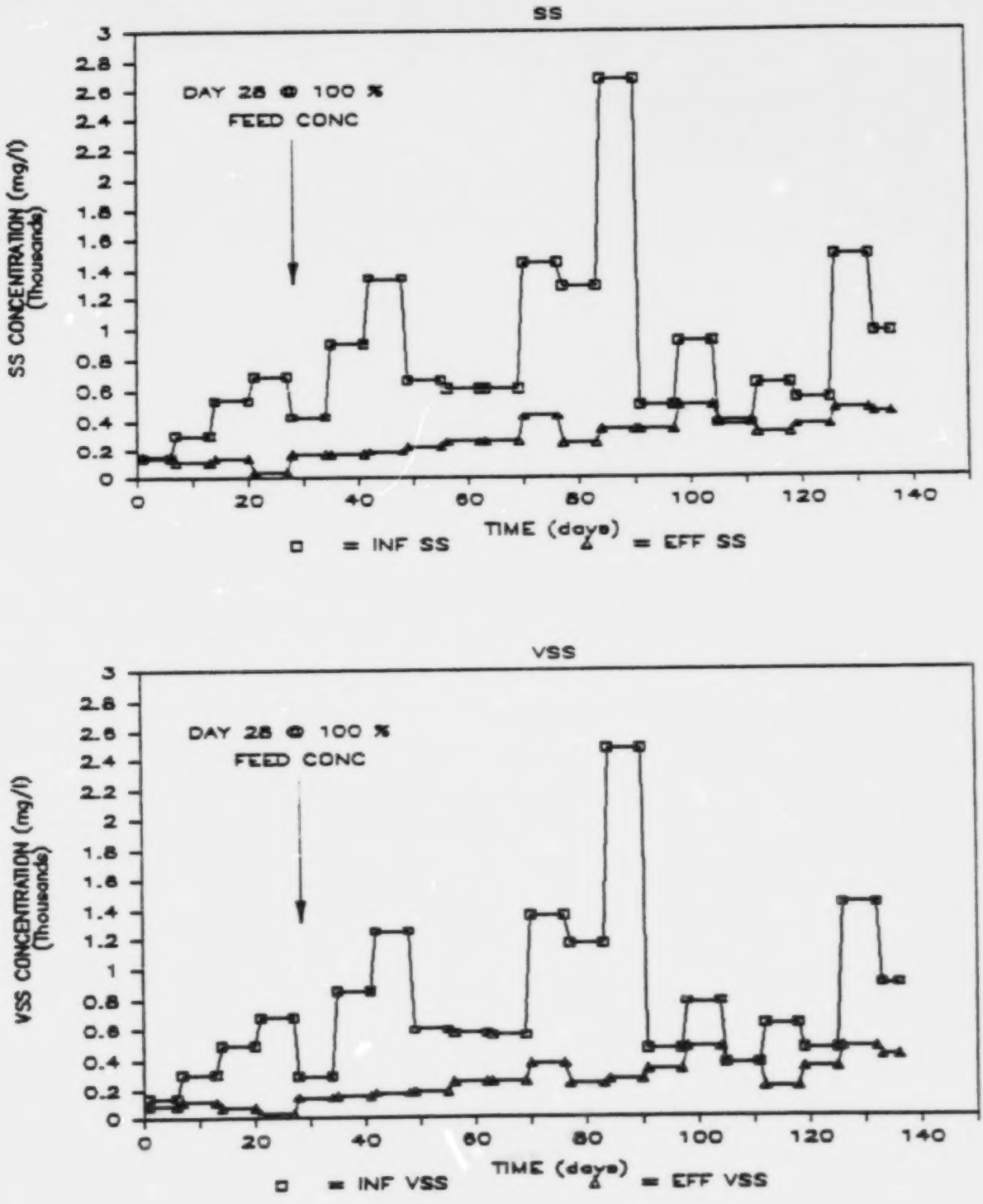


FIGURE 7.4

BVF #1 SS AND VSS CONCENTRATIONS

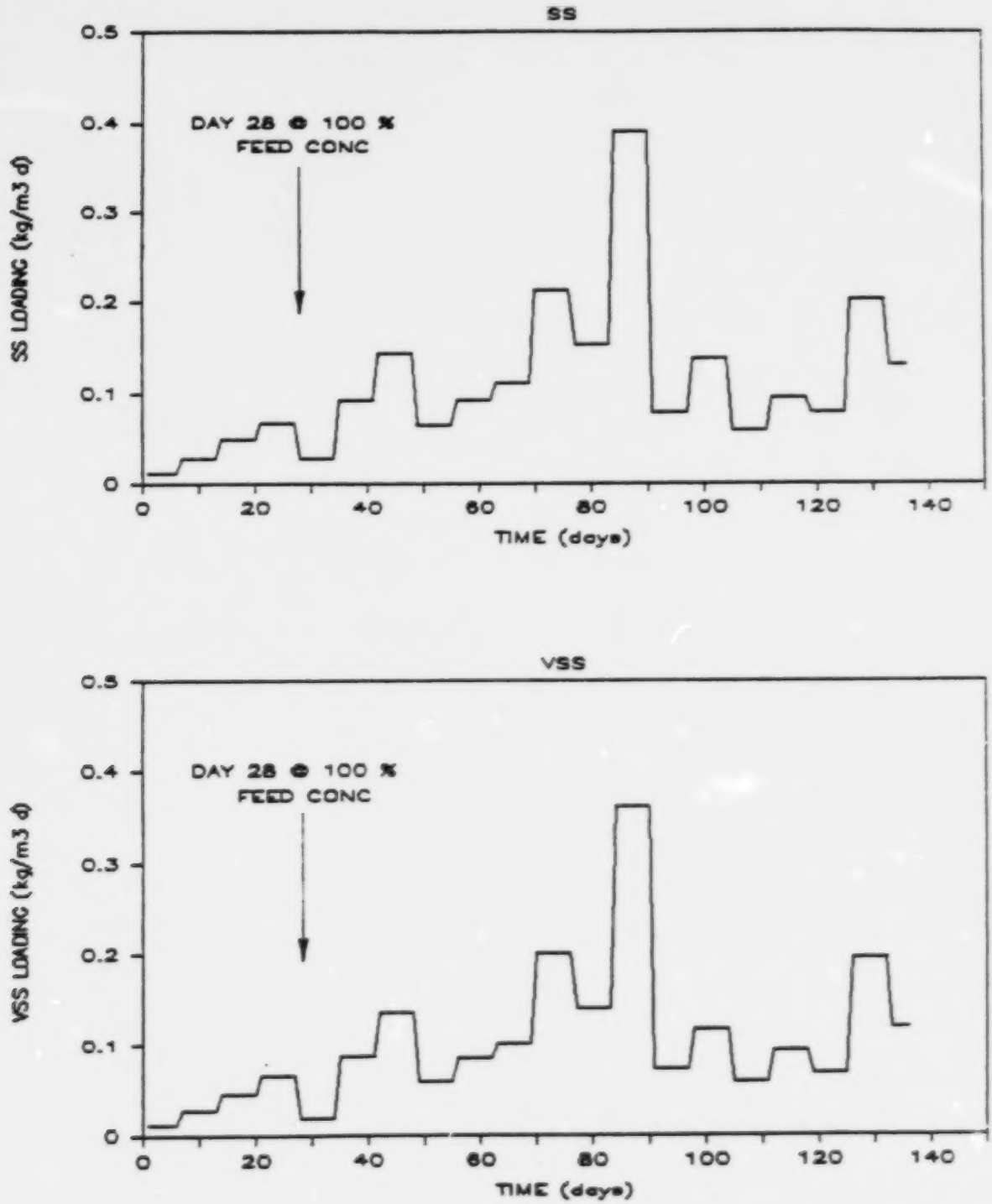


FIGURE 7.5

BVF #1 SS AND VSS LOADINGS

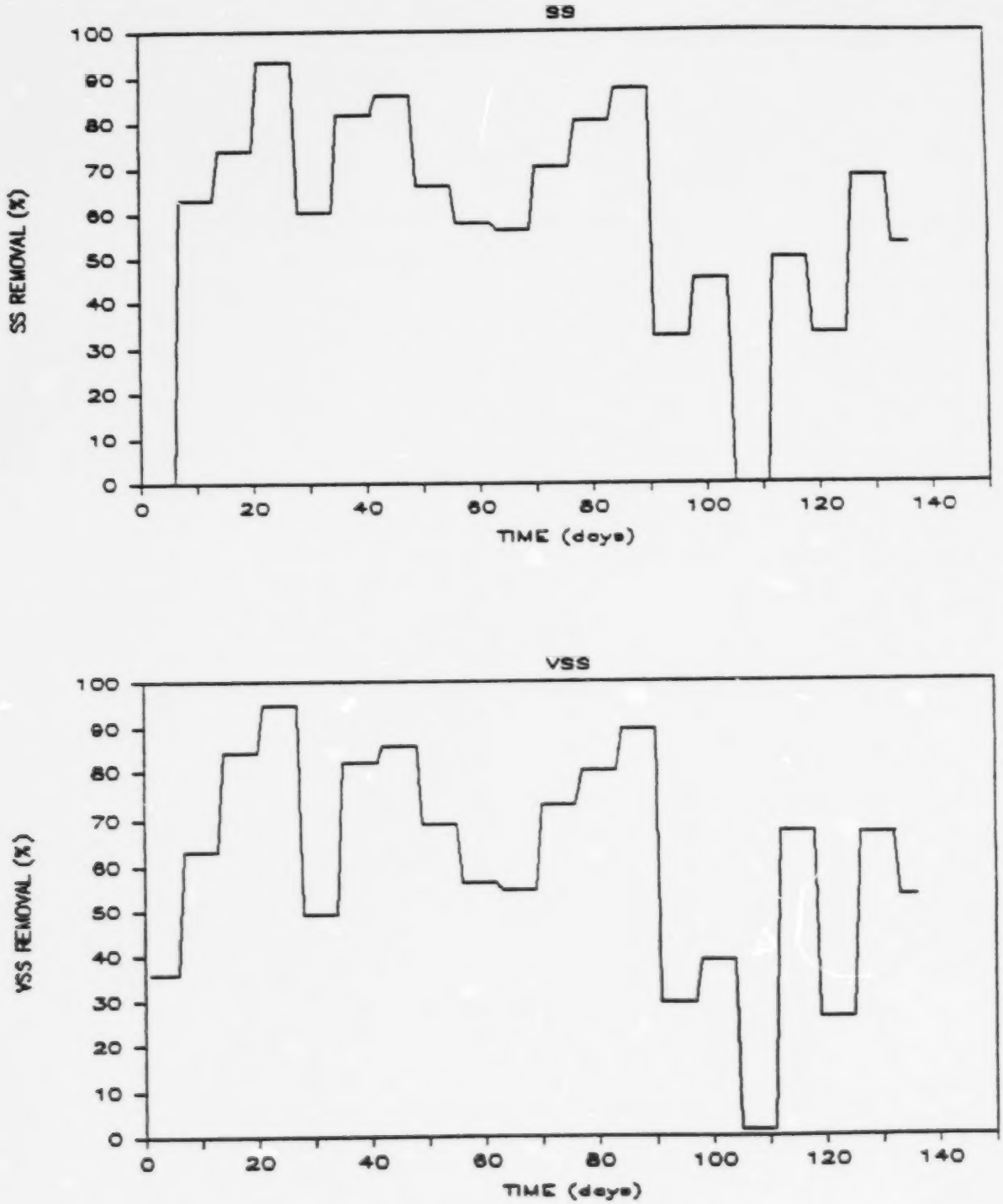


FIGURE 7.6

BVF #1 SS AND VSS REMOVALS

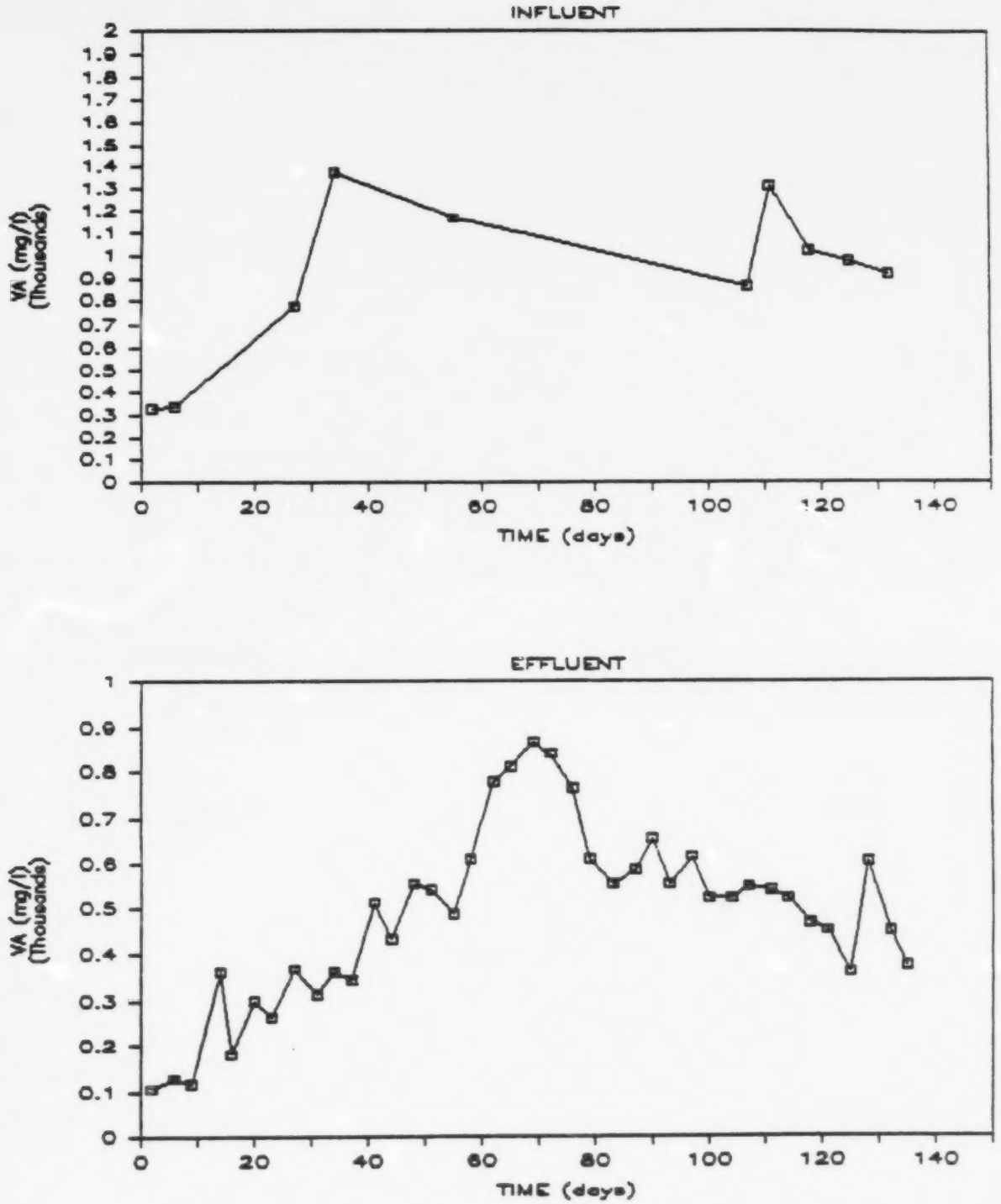
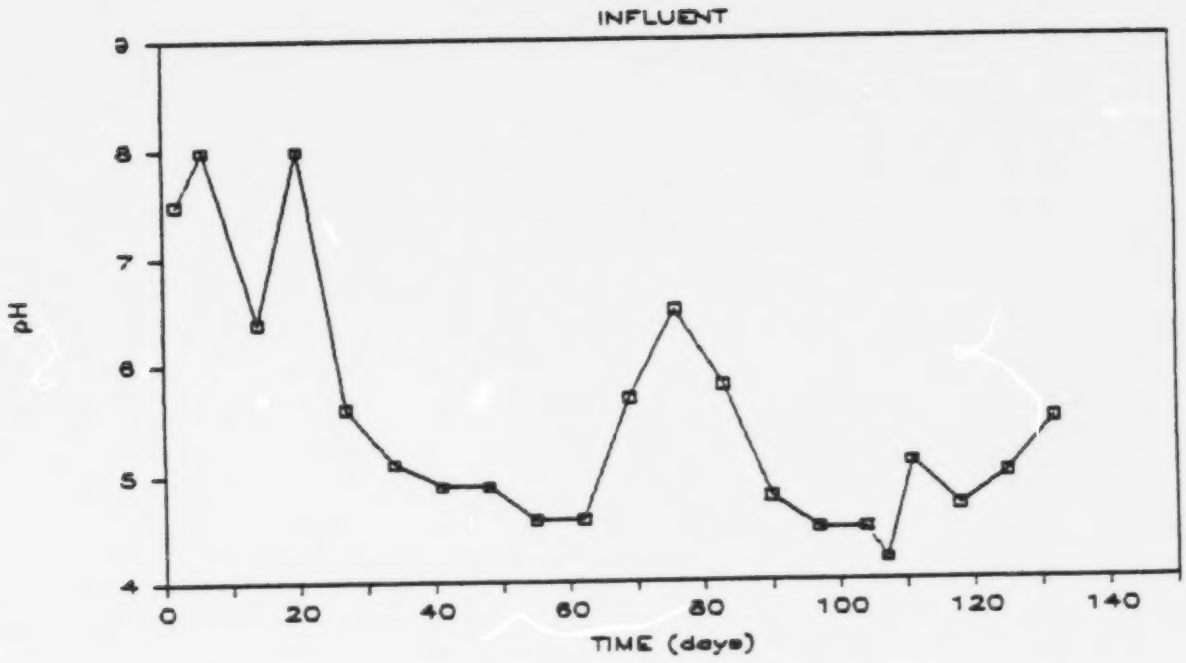


FIGURE 7.7

BVF #1 VA CONCENTRATIONS, INFLUENT AND EFFLUENT



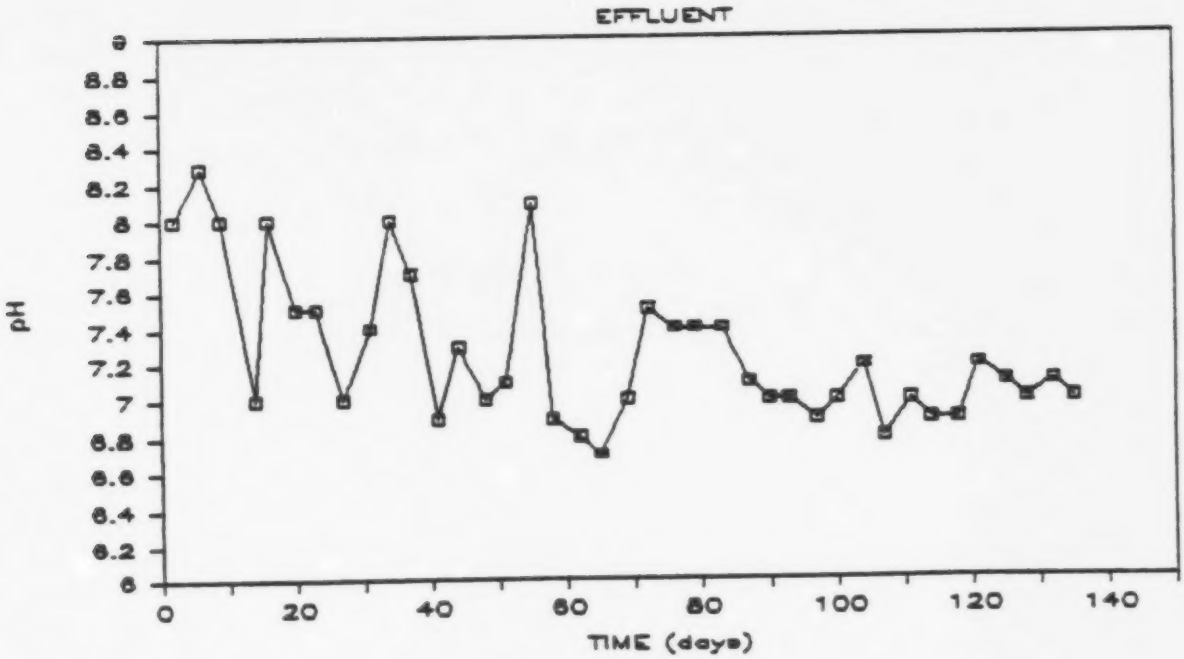
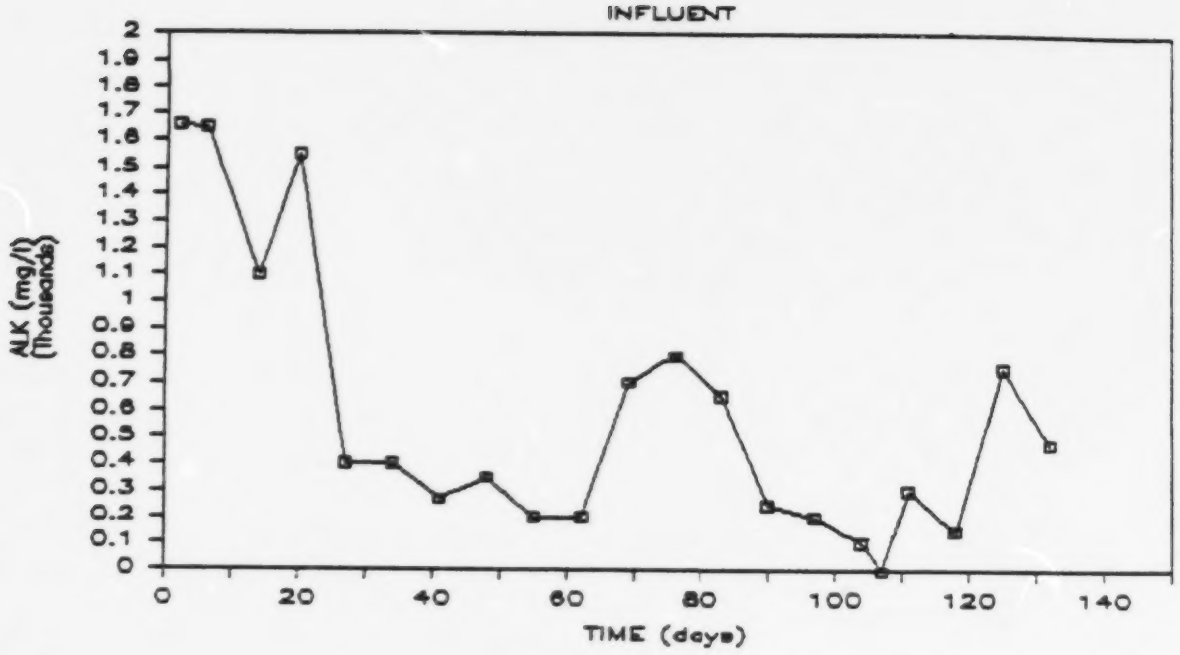


FIGURE 7.8

BVF #1 pH VALUES, INFLUENT AND EFFLUENT



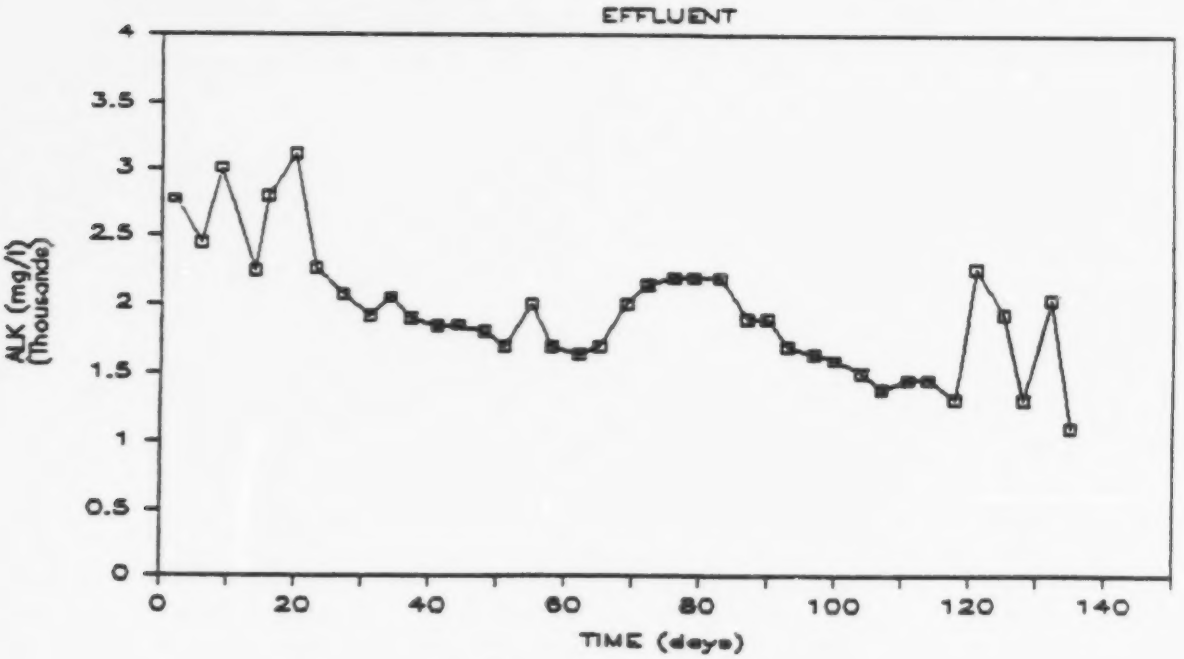


FIGURE 7.9

BVF #1 ALKALINITY CONCENTRATIONS, INFLUENT AND EFFLUENT

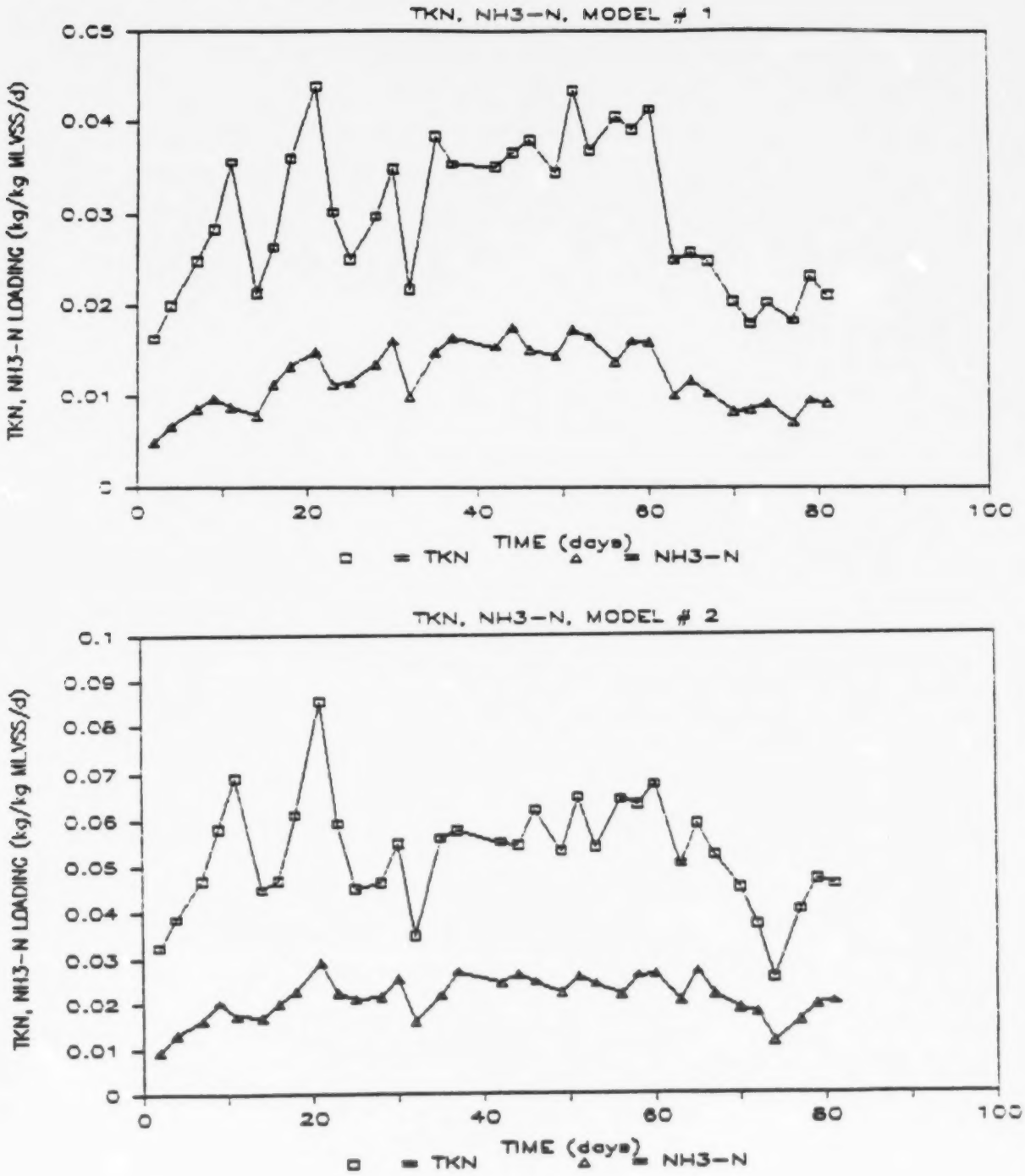


FIGURE 7.10

TKN AND NH_3-N LOADINGS:
NITRIFICATION-ACTIVATED SLUDGE
MODELS #1 AND #2

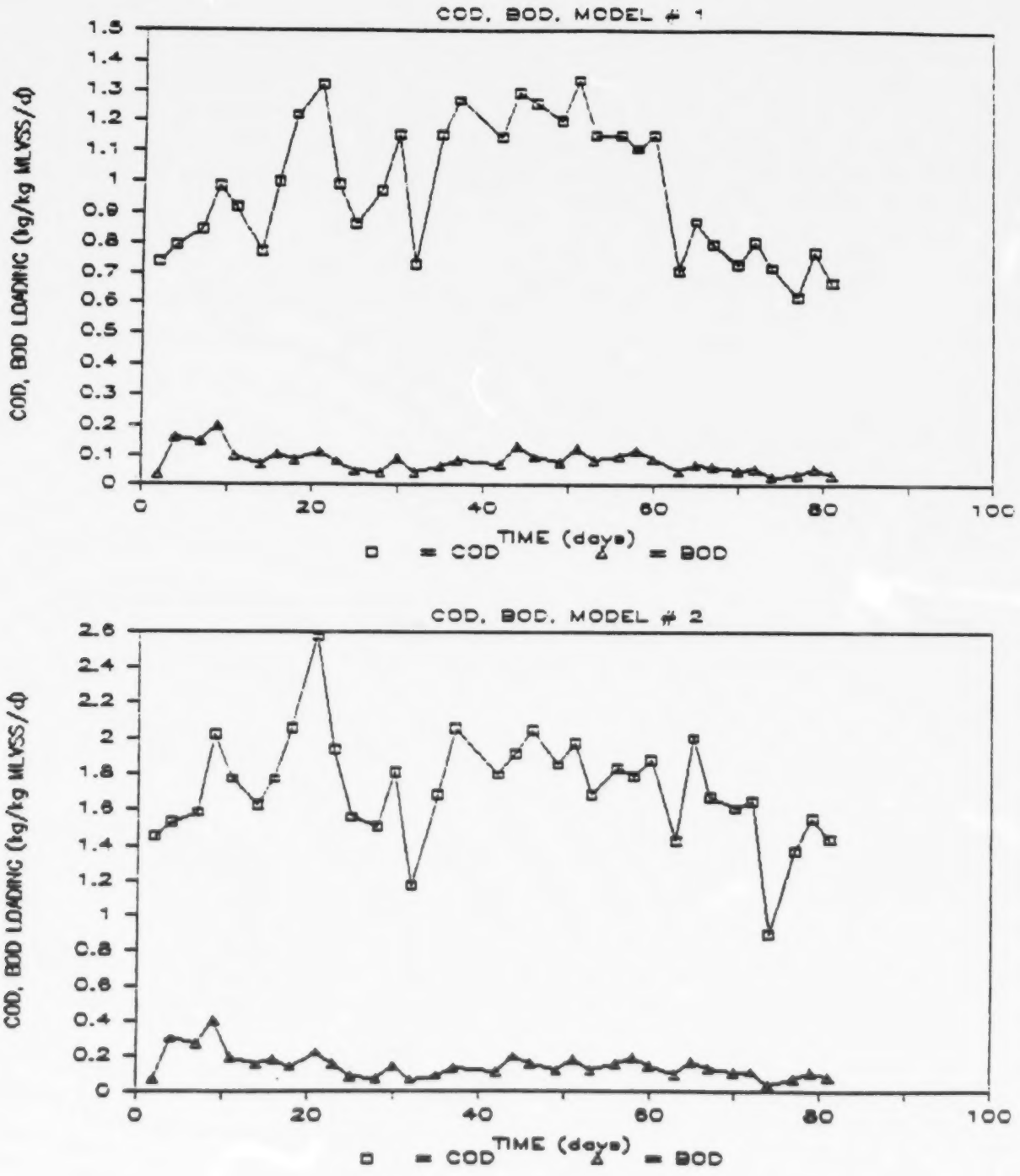


FIGURE 7.11

COD AND BOD LOADINGS:
NITRIFICATION-ACTIVATED SLUDGE
MODELS #1 AND #2

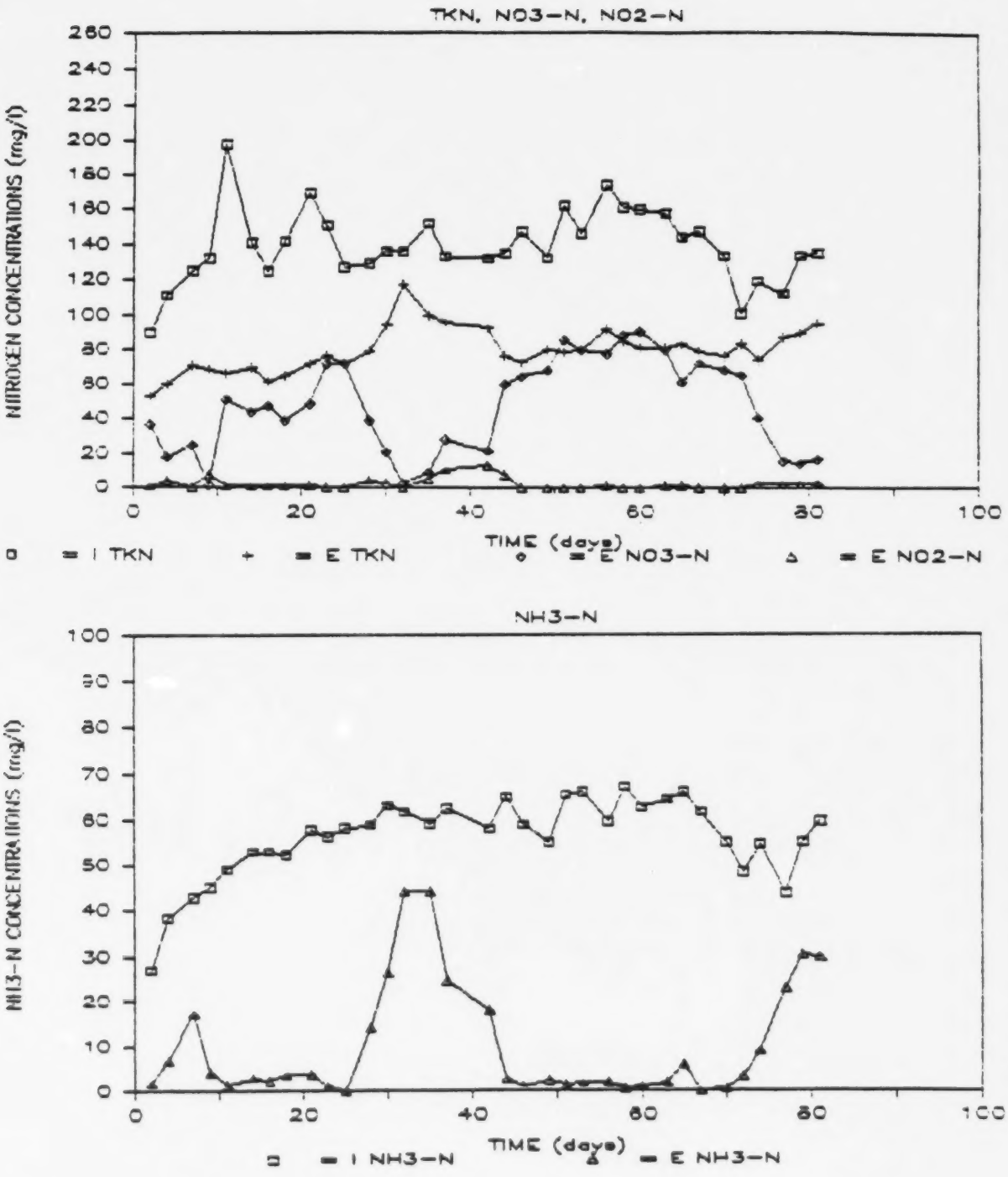
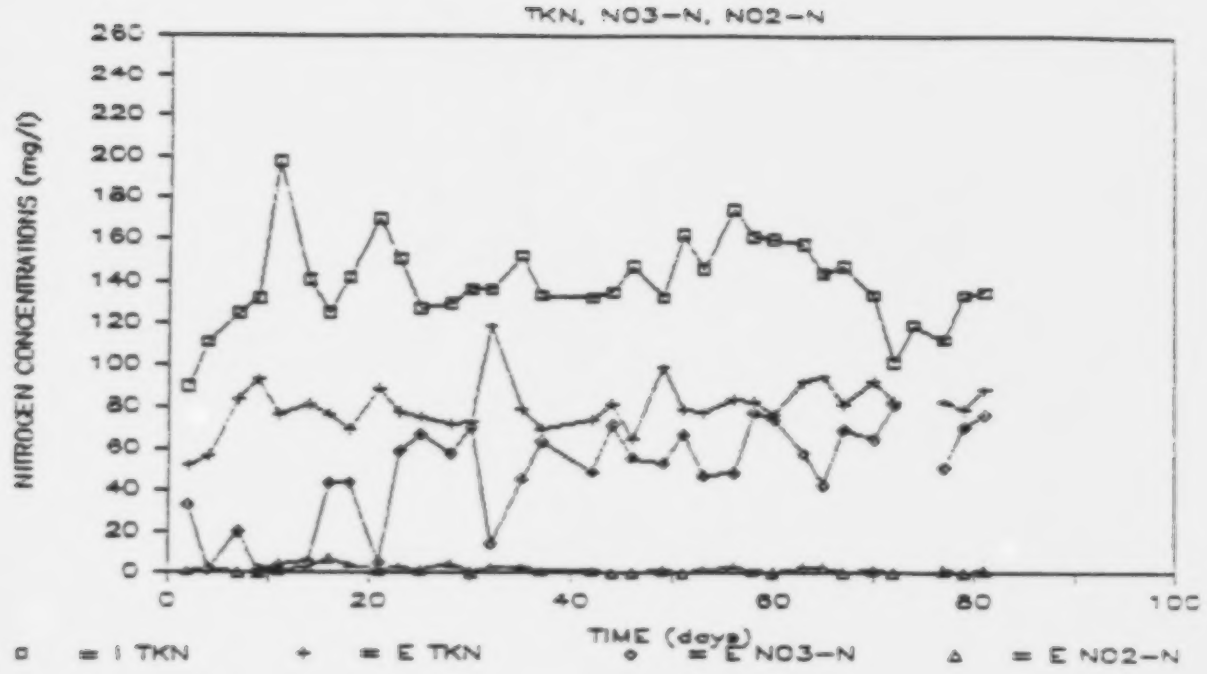


FIGURE 7.12

INFLUENT/EFFLUENT NITROGEN DATA:
NITRIFICATION-ACTIVATED SLUDGE
MODEL #1



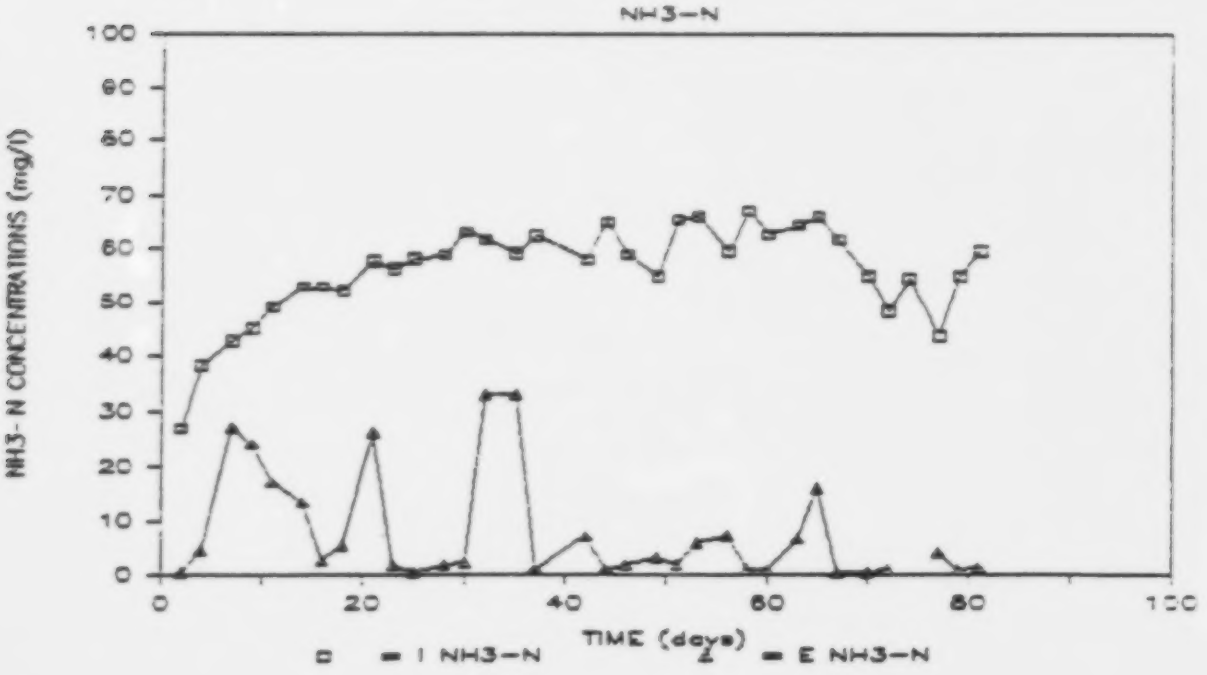


FIGURE 7.13

INFLUENT/EFFLUENT NITROGEN DATA:
NITRIFICATION-ACTIVATED SLUDGE
MODEL #2

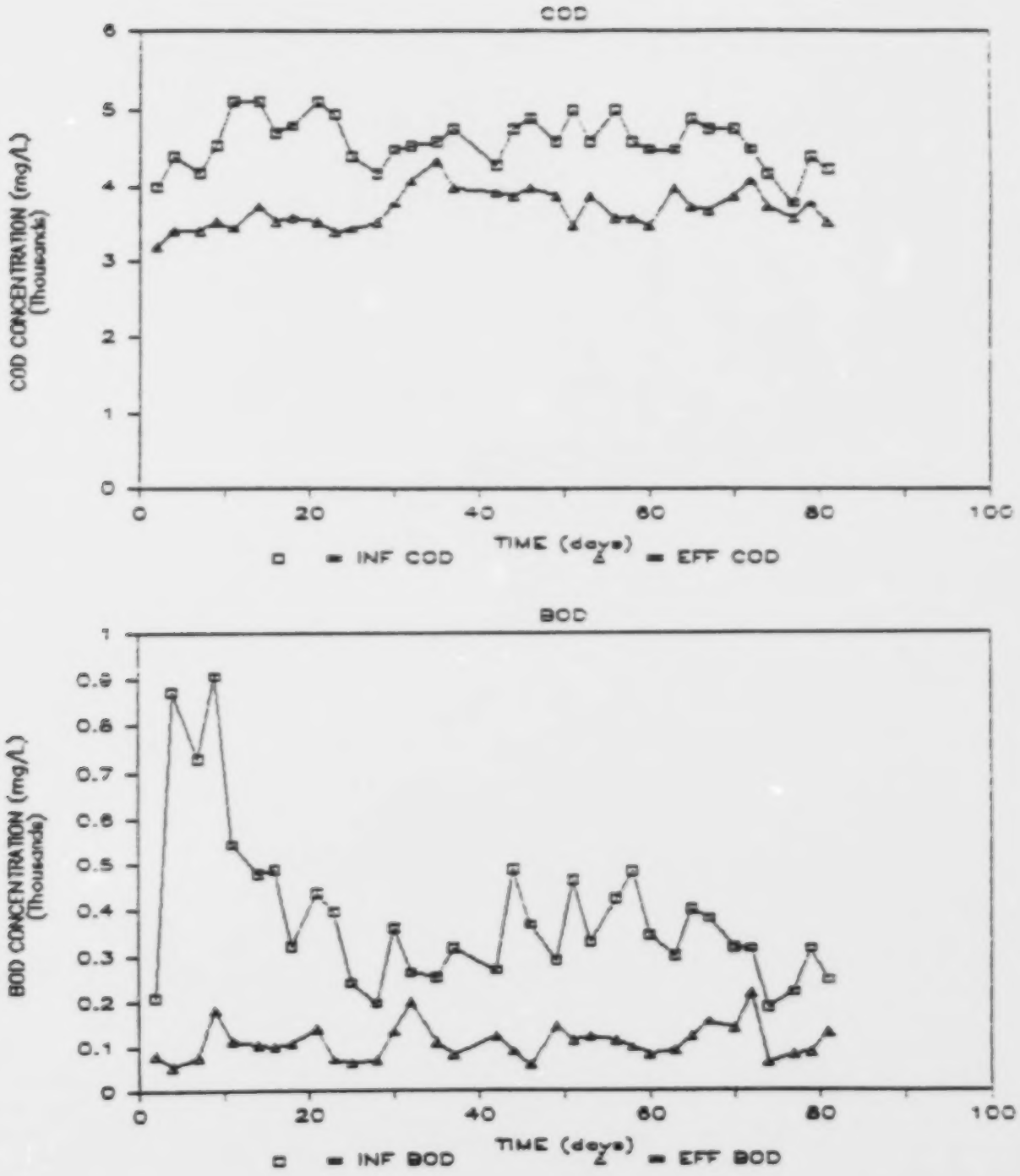


FIGURE 7.14

INFLUENT/EFFLUENT COD AND BOD:
NITRIFICATION-ACTIVATED SLUDGE
MODEL #1

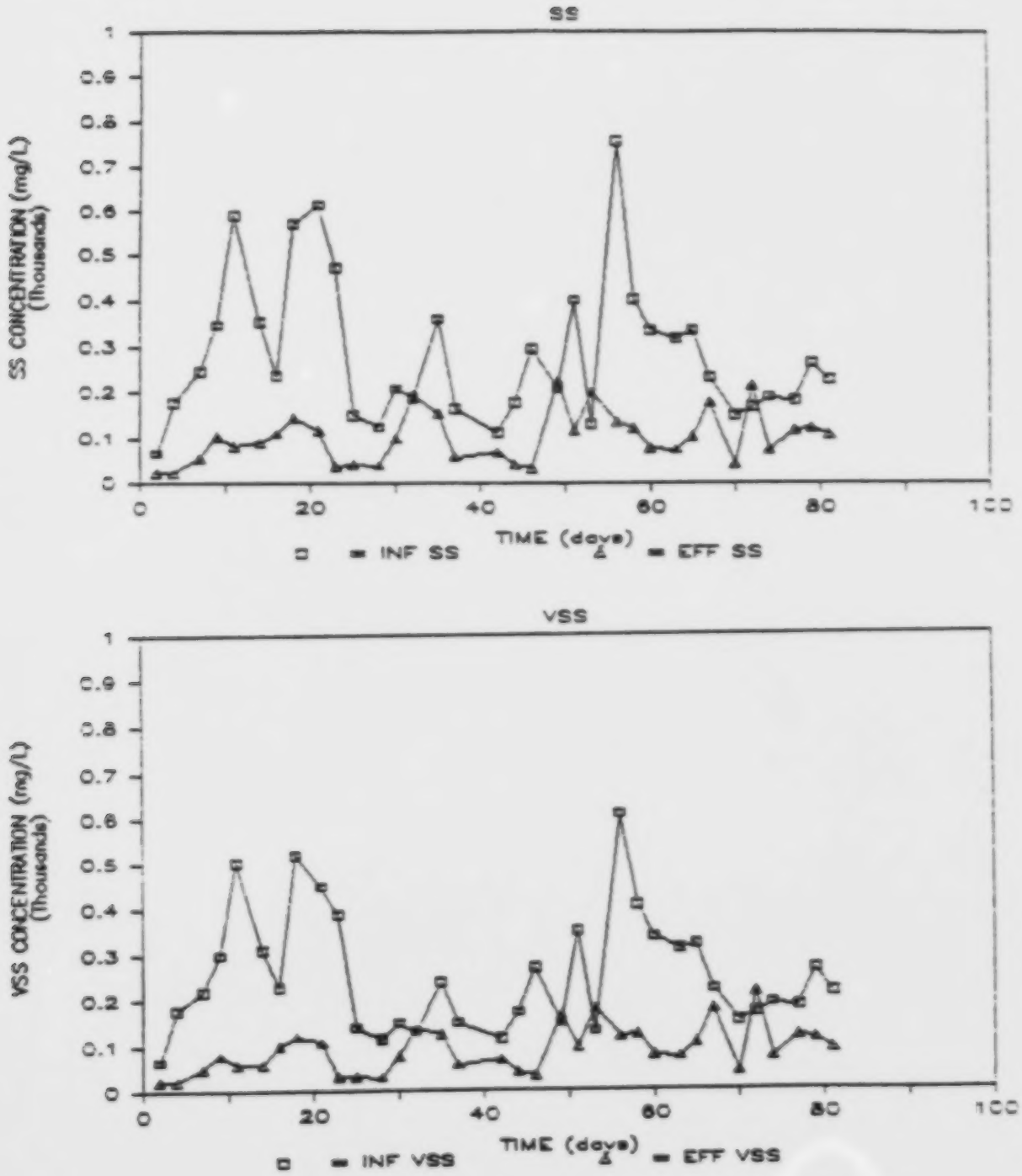


FIGURE 7.15

INFLUENT/EFFLUENT SS AND VSS:
NITRIFICATION-ACTIVATED SLUDGE
MODEL #1

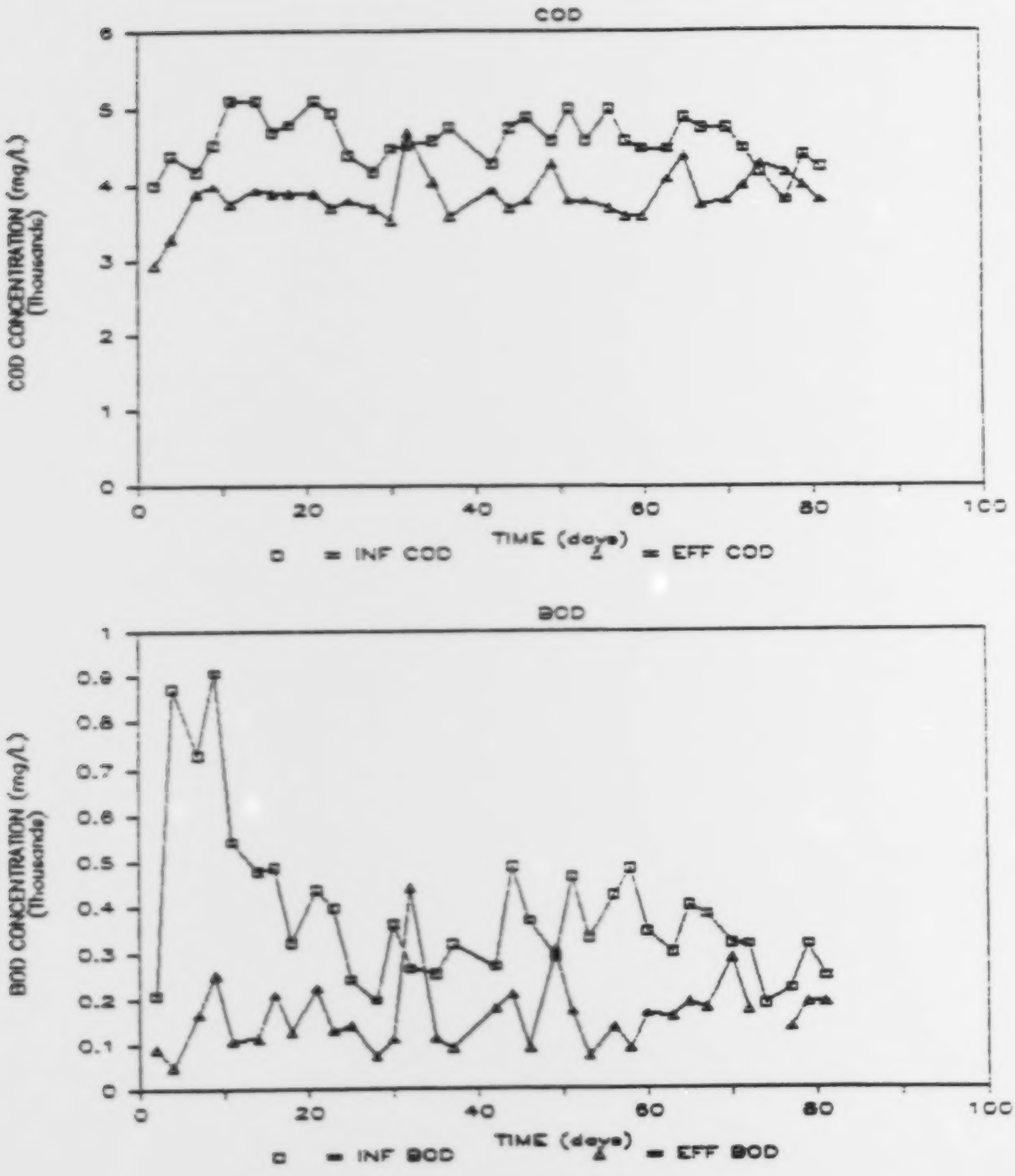


FIGURE 7.16

INFLUENT/EFFLUENT COD AND BOD:
NITRIFICATION-ACTIVATED SLUDGE
MODEL #2

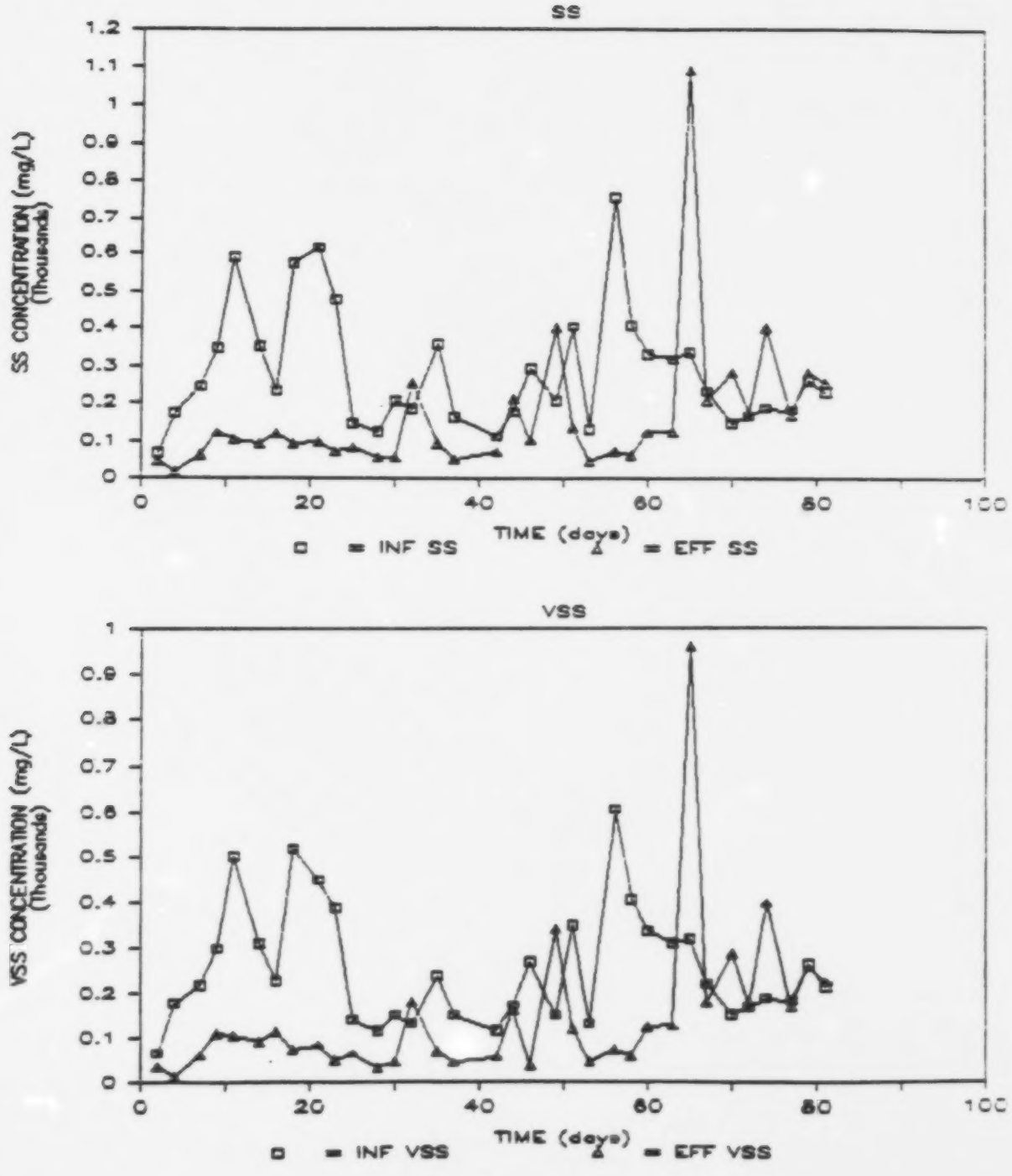


FIGURE 7.17

INFLUENT/EFFLUENT SS AND VSS:
NITRIFICATION-ACTIVATED SLUDGE
MODEL #2

8.0 DISCUSSION OF RESULTS

8.1 Performance of the BVF

Discussion of the BVF results will be limited to BVF #1, as it was more extensively monitored. From a comparison of BOD values of the BVF #1 effluent and the BODs of the nitrification systems' feed, which is a mixture of effluents from both BVFs, it can be concluded that the performance of BVF #2 was in fact somewhat better than that of BVF #1. VA concentrations encountered in BVF effluents were similar for the two reactors.

Results from BVF #1 indicate that wet-carb peat pressate can be effectively treated and with a high degree of performance using the ADI-BVF. There was no evidence of biological toxicity during the study. At one point early in the study, a low stress level was noted in the reactor as indicated by rising VA concentrations and falling pH values; the condition occurred between days 58 and 69. Following only the addition of extra $NaHCO_3$ to ensure adequate pH control, the system returned to more "normal" pH levels and VA levels in the range 400 and 550 mg/L. As was noted in a previous study on ORF WETOX^R peat pressate[1], a positive interference in the VA test used here resulted in values much higher than those encountered in split samples analyzed at NRC, using a gas chromatograph. Table 8.1 shows a comparison of VA results using the titration method[4] used at ADI and gas chromatograph. This data shows that the actual VAs in the reactor were significantly lower than that indicated by the VA titration test. The VA results generated using the titration method were nevertheless quite useful in establishing stress trends in the system and for reactor control purposes.

TABLE 8.1 COMPARISON OF VA RESULTS BY TITRATION AND GAS CHROMATOGRAPH

Sample	mg/L VA, Expressed as Acetic Acid: Titration (ADI)	GC (NRC)
Influent	1168	549
Effluent #1	488	40
Effluent #1	780	389
Effluent #1	653	200
Effluent #1	555	142
Effluent #1	615	189
Effluent #1	360	70
Effluent #1	180	30
Effluent #1	300	30
Effluent #1	261	60
Effluent #2	580	299
Effluent #2	668	259
Effluent #2	600	172
Effluent #2	570	100

The maximum loadings achieved in the BVF were approximately 2.5 kg COD/m^3 d and 1.0 kg BOD/m^3 d, during which the removals were approximately 72 and 90 percent, respectively. However, these two values were somewhat higher than the loadings typically encountered throughout most of the steady-state operation (loadings of approximately 2.1 kg COD/m^3 d and 0.7 kg BOD/m^3 d and removals of approximately 63 and 85 percent). This was due to an influent feed of unusually high strength (approximately 19000 mg/L COD and 7800 mg/L BOD). BOD removals during steady-state operation (day 70 onwards) showed a generally increasing trend, which indicated that the system was "maturing". As BOD removals increased, VA concentrations generally decreased, which is also an indication of "maturing". For the purpose of developing full-scale BVF costs, COD and BOD loadings of approximately 2.0 and 0.7 kg/m^3 d, and removals of 65 and 85 percent, respectively, were used here.

Suspended solids removal in the BVF averaged approximately 52 percent during steady state operation with the average effluent value being approximately 400 mg/L. The solids loading to the reactor was erratic, showing a variation from 0.06 to 0.39 kg/m^3d (the influent SS showed substantial fluctuation, averaging 1080 mg/L and having a SD of 685 mg/L). These variations contributed to the poor SS removals and were partially due to the change in SS characteristics from barrel #1 (Chemo Peat Pressate) and barrel #2 (Sunkhaze Peat Pressate). The changeover from barrel #1 to #2 occurred midway through the study. Another contributing factor may have been due to sample differences which occurred when the contents of each barrel were transferred to five gallon plastic containers for freezing and storage.

Other factors which likely contributed to the poor removals were the biogas mixing activity and the nature of the solids which had poor settling characteristics.

A solids mass balance was made for BVF #1 to determine the amount of solids digested in the reactor and the rate of solids accumulation. This analysis ignores the biomass produced in the reactor and is thus somewhat conservative.

The results are summarized below:

SS at start of study - 122.3 g approximately (30% full)
SS deposited in the reactor (from Table 8.2) - 63.9 g
SS at end of study - 184.8 g (approximately 40% full after 20 weeks)

These results indicate that very little of the SS (1.4 g) was destroyed or digested throughout the course of the study. The results of a previous study [1] revealed similar results with a BVF. However, in that earlier study, the BVF results were discounted as they appeared in error. The downflow filter results indicated significant volatile solids destruction and were more in line with previous observations (with other wastes) in this lab and by others. Now it is believed that suspended solids in the peat wet-carb (and WETOX^{R}) pressate may be largely biologically refractory due to either a high lignin and/or carbon content.

Based on these observations, sludge wastage will be necessary, perhaps on a semicontinuous basis. However, an accurate sludge wastage program can only be determined from actual operating experience and is largely dictated by the suspended solids concentration of the actual waste.

TABLE 8.2 : BVF # 1 SUSPENDED AND VOLATILE SUSPENDED SOLIDS DATA

DATE (from)	DATE (to)	DAYS (from)	DAYS (to)	INFLUENT SS (mg/l)	INFLUENT VSS (mg/l)	EFFLUENT SS (mg/l)	EFFLUENT VSS (mg/l)	FEED VOL (l)	INFLUENT SS (g)	INFLUENT VSS (g)	EFFLUENT SS (g)	EFFLUENT VSS (g)
85 1 2	85 1 7	1	6	140	140	157	90	3.5	0.490	0.490	0.550	0.315
85 1 8	85 1 14	7	13	305	305	113	113	4.4	1.342	1.342	0.497	0.497
85 1 15	85 1 21	14	20	540	490	140	78	4.0	2.160	1.960	0.560	0.312
85 1 22	85 1 28	21	27	696	678	44	34	4.5	3.132	3.051	0.198	0.153
85 1 29	85 2 4	28	34	430	290	170	147	2.9	1.247	0.841	0.493	0.426
85 2 5	85 2 11	35	41	912	852	166	152	4.4	4.013	3.749	0.730	0.669
85 2 12	85 2 18	42	48	1347	1253	187	173	5.0	6.735	6.265	0.935	0.865
85 2 19	85 2 25	49	55	667	593	224	184	4.1	2.735	2.431	0.918	0.754
85 2 26	85 3 4	56	62	615	567	257	248	7.0	4.305	3.969	1.799	1.736
85 3 5	85 3 11	63	69	609	552	265	250	8.1	4.933	4.471	2.147	2.025
85 3 12	85 3 18	70	76	1447	1353	431	365	6.8	9.840	9.200	2.931	2.482
85 3 19	85 3 25	77	83	1284	1168	250	230	5.3	6.805	6.190	1.325	1.219
85 3 26	85 4 1	84	90	2675	2470	339	261	6.4	17.120	15.808	2.170	1.670
85 4 2	85 4 8	91	97	505	467	340	330	7.0	3.535	3.269	2.380	2.310
85 4 9	85 4 15	98	104	920	780	500	478	6.9	6.348	5.382	3.450	3.298
85 4 16	85 4 22	105	111	376	376	402	370	7.0	2.632	2.632	2.814	2.590
85 4 23	85 4 29	112	118	635	625	318	206	6.4	4.064	4.000	2.035	1.318
85 4 30	85 5 6	119	125	543	465	364	342	6.5	3.530	3.023	2.366	2.223
85 5 7	85 5 13	126	132	1486	1430	476	476	5.9	8.767	8.437	2.808	2.808
85 5 14	85 5 17	133	136	974	902	454	421	2.5	2.435	2.255	1.135	1.053
						SUM			96.167	88.766	32.241	28.725
						SOLIDS DEPOSITED			SS= 63.926		VSS= 60.041	

An estimate of the sludge wastage frequency was made using results from this study. Initially, the BVF was 30 percent full with sludge. After 20 weeks of operation, the BVF was approximately 40 percent full of sludge. At this rate and assuming that the full-scale BVFs will be 10 percent full of sludge at startup and wasting will be required when it is 50-60 percent full, the BVF would require intermittently-continuous sludge wasting after approximately 1.5 to 2 years of operation.

The average specific methane generation determined from Table 7.3 was approximately 0.27 m^3 CH_4 (STP)/kg COD removed, which is approximately 77 percent of the theoretical value of 0.35 m^3/kg. This is somewhat lower than would normally be expected (typical values are generally in the range of 85-95+ percent of theoretical). In the previous study values of 0.31 and 0.35 m^3 CH_4 (STP)/kg COD removed were measured for the downflow filter and BVF, respectively. One of the reasons for a low recovery of methane is the accumulation of volatile solids in the reactor. When this is taken into account, the specific generation rate becomes 0.30 m^3 CH_4 (STP)/kg COD destroyed, which is approximately 85 percent of the theoretical value.

Other reasons for low CH_4 recovery can include CH_4 dissolution in the effluent, errors in gas quantity and composition measurements, errors in sampling and in COD testing.

The CH_4 content of the biogas throughout the study varied from 56 percent to 81 percent. However, the variation was much less pronounced during the steady state period of operation (56-66 percent) reflecting more stable conditions within the reactor.

With the exception of two initial values, the H_2S concentration in the biogas was below 50 ppm, with many values at 0 ppm. This is a reflection of the low sulfur content of the pressate (0.017 percent), and should not cause any serious handling problems.

The average effluent sulfide concentration in the BVF was approximately 3.5 mg/L (reference Table 7.2). With subsequent aerobic treatment, any sulfide should be eliminated and there should not be any problem with sulfide toxicity to fish.

Average results shown in Table 7.1 indicate a TKN "loss" of 28 mg/L from the BVF effluent. The most likely and logical place for this TKN "loss" to report is to the biogas stream in the form of NH_3 gas. This ammonia gas would have been stripped by the biogas activity in the reactor. Calculations indicate that this loss will produce approximately 38 mL NH_3 (gas)/d. This would represent approximately 1.3 percent of the biogas produced. The biogas was not analyzed for its ammonia content.

The BOD/N/P (N as NH_3) ratio of the raw pressate was found to be approximately 500/5/1.5. While this ratio is low for aerobic treatment, it should be sufficient to satisfy the requirements of the BVF, thus avoiding the addition of N and P in full-scale. It is doubtful, because of the nature of the waste, and from the results of this study that any micronutrient supplementation will be necessary.

Chemicals for pH control were added throughout the study. Such chemicals would be required in full-scale on this waste as it contains no background alkalinity and only enough NH_3-N to produce the equivalent of approximately 400 mg/L alkalinity. This level would not be high enough to ensure stable operation of the BVF. For purposes of developing full scale O&M costs, it was assumed that 100 mg/L of NaOH would be required on a continuous basis.

It is of interest to compare the results obtained during this study with those obtained in a previous study[1] treating WETOX^R peat pressate. The previous study showed average COD, BOD and

SS removals of 60-70 percent, 80-90 percent and 30-35 percent, respectively, which, with the exception of SS removals, is very similar to the results obtained in this study. Maximum loadings of 2.5 kg COD/m^3d and 1.0 kg BOD/m^3d were achieved during this study, compared with 2.3 and 0.7, respectively, in the previous study. However, the maximum loadings in this study were due to an unusually high strength waste, and were not typical of the loadings maintained during steady state (approximately 2.1 and 0.7). The CH_4 concentrations in the biogas are similar for both studies (averaging approximately 65 percent). However, the specific methane generation rate in this study (0.27) differs significantly from the results obtained in the previous study (0.31 for DFF and 0.35 for BVF).

Perhaps the major difference in the two studies lies in the addition of chemicals for pH and alkalinity control which is dictated by the NH_3 concentration in the waste (and reactor effluent) which in turn is largely controlled by the nitrogen content of the raw peat and processing conditions. In the WETOX^R study, it was concluded that the addition of chemicals was unnecessary as the ammonia levels in the raw waste and BVF effluent were high enough (approximately 220 mg/L NH_3-N) to generate a sufficient quantity of alkalinity (approximately 1300 mg/L) to ensure safe operation of the BVF. In this study, the ammonia levels are much lower (approximately 45 mg/L in the BVF influent and 70 mg/L in the effluent) and thus do not generate as much alkalinity.

8.2 Discussion of Operational Data: Nitrification-Activated Sludge Models #1 and #2

The activated sludge models represented combined, suspended growth, carbon oxidation-nitrification systems. The oxidation of carbonaceous substrate (i.e., organic matter) by a heterotrophic bacteria population, and the oxidation of ammonia

nitrogen by a chemo autotrophic nitrifying bacteria population were carried out simultaneously in the aeration cell of both models.

The nitrifiication process is performed by aerobic bacteria collectively termed nitrifiers. Two sequential reactions are carried out by the nitrifiers, the first step involves the oxidation of NH_4-N TO NO_2-N by the genus Nitrosomonas, the second step involves the oxidation of NO_2-N to NO_3-N by the genus Nitrobacter. Both bacteria groups utilize inorganic carbon for synthesis of biomass. The nitrification reaction equations are presented below:

$$2NH_4^+ + 3O_2 \xrightarrow{\text{Nitrosomonas}} 2NO^-_2 + 4H^+ + 2H_2O$$

$$2NO^-_2 + O_2 \xrightarrow{\text{Nitrobacter}} 2NO^-_3$$

$$\text{Overall} \quad NH^+_4 + 2O_2 \longrightarrow NO^-_3 + 2H^+ + H_2O$$

The average HRT and BOD loadings established in models #1 and #2 (see Table 7.5) are typical of an activated sludge extended aeration operating mode. Evidence in the literature[6] has shown that at low BOD loadings (i.e., low F/M ratios) and high SRT (solids retention time) values, a high degree of nitrification and carbonaceous removal is achievable under a wide range of operating temperatures.

The nitrification process is highly dependent upon maintaining a sufficient population of autotrophic nitrifying organisms. This requires that adequate SRT be provided to avoid a washing out effect of nitrifying organisms from the system. Because the

growth rate of autotrophic nitrifying organisms is significantly less than that of heterotrophic organisms, correspondingly higher SRTs are required for nitrification versus carbonaceous removal.

Recently published nitrification research conducted on industrial wastewaters containing high concentrations of NH_3-N[7] was conducted at SRT values of 20 days or more. The minimum SRT for effective nitrification of coal gasification wastewater was found to be 22 days.[7] The same study also indicated that better nitrification performance was achieved under conditions of longer (40 versus 22 days) SRT. A study involving activated sludge treatment of high strength nitrogenous waste [9] achieved high NH_3-N removal efficiency (96%) at an SRT = 8.5 days. A similar removal efficiency (97%) was obtained in the same study at an SRT = 21 days. However overall, both TKN and NH_3-N removals were found to be lower at shorter SRT values.

It was intended in this study to maintain a minimum SRT of 20 days during all phases of operation. Long SRT's would allow the nitrifier population to become better established, resulting in a more efficient nitrification process. Long SRTs were promoted by minimizing the amount of solids lost from the aeration cell. The sources of solids loss included solids escaping in the settling chamber effluent and solids withdrawn from the aeration cell for MLSS/MLVSS analysis. SRT values for both models were calculated for each temperature phase of operation on the basis of the following equation:

$$SRT = \frac{\text{aeration basin biomass inventory}}{\text{biomass removed from aeration cell for analytical purposes} + \text{biomass escaping in the effluent}}$$

The SRT values determined for each phase of operation for both models #1 and #2 are presented in Table 7.5. Sludge retention times greater than 20 days were maintained in all phases for model #1. However, for model #2, a SRT greater than 20 days was achieved only for phase 1 operation, although the SRT for phase 2 was 18 days. The SRT for model #2 during phase 3 was 7 days.

Although no sludge was purposely wasted from model #2, the inability to maintain a high SRT during phase 3 was attributed to; (a) poor solids settling in the effluent settling chamber, as evidenced by the increased effluent SS and VSS concentrations, and (b) removal of solids from the aeration cell for MLSS/MLVSS analysis. Sludge bulking, the result of filamentous bacteria domination, can often be the cause of poor solids settling in extended aeration applications of the activated sludge process. Solids removal from the aeration cell for MLSS/MLVSS analysis was increase during phases 2 and 3 in order to more closely monitor mixed liquor concentration. As a result, this solids wasting for analytical purposes was partially the blame for a SRT less than 20 days in model #2 phase 2 and 3 operations.

8.3 Discussion of Nitrogen Results: Nitrification-Activated Sludge Models #1 and #2

8.3.1 General

Nitrogen data for models #1 and #2 (Table 7.6) indicate averages influent TKN concentrations of 137, 146, and 131 mg/L, and average influent NH_3-N concentrations of 48.5, 61.5, and 56.4

mg/L for phases 1, 2 and 3 respectively. The percent NH_3-N of the total TKN were determined as 35.4 percent (phase 1), 42.1 percent (phase 2) and 43.1 percent (phase 3). These figures show that more than 50 percent of the influent TKN (anaerobic process effluent TKN) to the aeration process is in the organic nitrogen form. In order for the organic nitrogen portion to be available for nitrification it must first be converted to NH_3-N by ammonification.

8.3.2 Nitrification-Activated Sludge Model #1

On the basis of the selected nitrogen data for each of the three temperature phases (see Table 7.9), overall TKN removals were determined as 54.2 percent (22°C), 47.3 percent (17°C), and 41.0 percent (15°C). Average effluent NH_3-N concentrations were calculated to be 2.3 mg/L (22°C), 1.6 mg/L (17°C), and 2.6 mg/L (15°C). At these levels, it can be assumed that nearly complete nitrification occurred at all operating temperatures.

Overall percent NH_3-N removals were not determined directly from influent and effluent NH_3-N data presented in Table 7.9. In determining overall NH_3-N removals, it was necessary to account for the ammonification phenomenon. Ammonification, or conversion of organic nitrogen to NH_3-N, occurs as a result of mineralization of organic nitrogen compounds and the subsequent biological conversion. Mineralization of organic nitrogen involves the release of inorganic forms of nitrogen during its microbial degradation. Therefore, the total NH_3-N input to the aerobic process includes the initial influent NH_3-N plus that portion of the influent organic nitrogen ammonified to ammonia nitrogen during the aerobic treatment process. The portion of organic nitrogen converted to ammonia nitrogen in this study was determined as the difference in influent and effluent organic nitrogen concentrations.

Organic nitrogen concentrations were not determined analytically in this study, but calculated as the difference between measured TKN and NH_3-N concentrations (i.e., TKN = organic nitrogen + ammonia nitrogen). Average influent and effluent organic nitrogen concentrations were determined for phase 1 from Table 7.9 data as 95.7 mg/L (150 minus 54.3) and 66.4 mg (68.7 minus 2.3) respectively. The 29.3 mg/L (95.7 minus 66.4) organic nitrogen calculated as the difference between the influent and effluent organic nitrogen concentration represents additional NH_3-N input due to ammonification (29.3 mg/L organic nitrogen ammonified to 29.3 mg/L NH_3-N). On this basis, the total influent NH_3-N was calculated as 83.6 mg/L (54.3 + 29.3). On the basis of an average effluent NH_3-N of 2.3 mg/L, the overall NH_3-N removal was determined to be 97.2 percent at 22°C. Similarly, for phases 2 (17°C) and 3 (15°C) NH_3-N removals were determined as 97.8 percent and 95.6 percent, respectively.

8.3.3 Nitrification-Activated Sludge Model #2

From selected nitrogen data presented in Table 7.9, overall TKN removals were determined as 45.1 percent (22°C), 47.0 percent (17°C), and 33.3 percent (15°C). These removals are less than the corresponding model #1 removals, and reflect the effects of shorter HRT and SRT conditions under which model #2 operated. Average effluent NH_3-N concentrations were determined as 2.7 mg/L (22°C), 3.3 mg/L (17°C), and 1.5 (15°C). Nearly complete nitrification can therefore be assumed to have occurred at all operating temperatures.

Overall NH_3-N removals for model #2 were similarly determined as for model #1. By accounting for the additional NH_3-N input resulting from the ammonification of influent organic nitrogen, model #2 NH_3-N removals were calculated as 95.8 percent (22°C), 95.5 percent (17°C), and 97.2 percent (15°C).

8.4 Discussion of Carbonaceous and Solids Results: Nitrification-Activated Sludge Models #1 and #2

Removals for COD, BOD, SS and VSS were determined on the basis of influent and effluent data (Appendix E, Tables E.1 and E.2) for each day of analysis. Complete removal data for both models #1 and #2 are presented in Appendix G, Tables G.1 and G.2 respectively. Average removals for each temperature phase are summarized in Table 8.3.

Removals presented in Table 8.3 show that less COD and BOD removal occurred at lower temperatures in both models #1 and model #2. Comparison of the two systems shows that a better COD and BOD removal performance was achieved by the longer HRT established in model #1. A comparison of suspended solids removal data shows that better overall removals were also achieved by model #1. Inspection of model #2 SS and VSS phase 3 effluent data (Appendix E, Table E.2) reveals exceedingly high effluent concentrations. The excessive loss of biomass signified an upset condition attributed to poor solids settling in the effluent settling chamber. This significant increase in effluent solids is also directly responsible for the lower COD and BOD removals experienced during phase 3 with model #2.

8.5 Discussion of Nitrogen Balance Data: Nitrification-Activated Sludge Models #1 and #2

Nitrogen balances determined from data presented in Tables 7.7 and 7.8 indicate that, overall, total effluent nitrogen accounted for 92.7 percent in model #1 and 91.1 percent in model #2 of the total influent nitrogen. The average overall effluent TKN, NO_3-N and NO_2-N accounted for 57.1, 33.5, and 2.1 percent respectively of model #1 influent nitrogen, and 56.4, 33.3, and 1.4 percent respectively of model #2 influent nitrogen.

TABLE 8.3 SUMMARY OF CARBONACEOUS AND SOLIDS REMOVALS: NITRIFICATION-ACTIVATED SLUDGE MODELS #1 AND #2

Phase		Removals (%) COD	BOD	SS	VSS
Model #1					
1		25.0	77.2	75.0	76.5
	(SD)	(4.4)	(9.3)	(11.0)	(10.2)
2		17.1	65.5	53.1	51.9
	(SD)	(6.6)	(15.4)	(30.4)	(30.4)
3		14.4	59.0	48.9	49.1
	(SD)	(5.7)	(12.7)	(23.6)	(24.1)
Model #2					
1		19.8	66.5	69.4	70.2
	(SD)	(6.2)	(14.6)	(18.3)	(15.5)
2		17.0	54.6	53.2	56.2
	(SD)	(7.6)	(25.1)	(30.2)	(29.8)
3		10.1	38.6	8.8	10.0
	(SD)	(6.9)	(14.0)	(18.6)	(18.4)

The unaccounted for influent nitrogen was 7.3 percent in model #1 and 8.9 percent in model #2. This unaccounted for portion of influent nitrogen may be attributed to several factors. A recent nitrification study[7] found 9.8 percent of influent TKN to be unaccounted for in the effluent wastewater. The unaccounted portion was attributed to microbial cell growth and possible denitrification, air stripping, and analytical error. These same factors are also warranted here in explaining the apparent influent-effluent nitrogen discrepancy.

Due to low dissolved oxygen levels occurring in the effluent settling chamber, the possibility of denitrification of the aeration cell effluent during settling was investigated. Comparison of NO_2-N and NO_3-N measurements were made on samples obtained from the effluent settling chambers and aeration cells. Measurements were conducted for an extended period and the results confirmed that an insignificant amount of denitrification, if any, had occurred in the effluent settling chambers. Denitrification was therefore ruled out as contributing to the nitrogen imbalance.

Inherent to the extended aeration process is a maximization of endogenous respiration. Under stable operating conditions, no appreciable nitrogen loss to microbial growth would occur in either aeration cell due to the high degree of biomass respiration. Nitrogen incorporated within the cell for growth and maintenance purposes would be released upon cell respiration. For this reason, nitrogen loss due to microbial growth was not believed to have significantly contributed to the nitrogen imbalance.

Apart from analytical error, it is suspected that the unaccountable nitrogen is primarily the result of nitrogen loss due to air stripping. A study of the mechanism of ammonia removal in a single stage nitrification system having long HRT[5], reported that air stripping of ammonia was found to occur to a significant extent. The operating parameters of their bench-scale model were similar to those occurring in this study. It was also reported in the same study that denitrification in the clarifier section was not evident to account for the open nitrogen balance.

8.6 Potential Fish Toxicity of Ammonia Nitrogen and Nitrite Nitrogen

Nitrification at each operating temperature of both models was considered essentially complete for the duration of data selected as stable nitrification process operation. Average ammonia nitrogen effluent concentrations for all operating temperatures (22, 17, and 15°C) ranged for both models from 1.5 to 3.3 mg/L. Average NO_2-N effluent concentrations for the same data periods ranged from 1.0 to 3.9 mg/L.

Ammonia-nitrogen is considered toxic to fish only when in the un-ionized stage (i.e., the NH_3 molecule as opposed to NH_4^+). The extent of un-ionized ammonia nitrogen is pH and temperature dependent. The percentage un-ionized ammonia concentration increases with increasing pH and temperatures. In a study of un-ionized ammonia Trussel[9] presented a table showing the percentage of un-ionized ammonia in aqueous ammonia solutions at different pHs and temperatures. On the basis of this table and average NH_3-N effluent data, un-ionized NH_3-N concentrations were calculated for models #1 and #2. The results are given in Table 8.4.

Un-ionized NH_3-N effluent concentrations presented in Table 8.4 range from 0.007 to 0.29 mg/L for model #1 and from 0.004 to 0.33 mg/L for model #2. Russo and Thomann[10] reported the findings of numerous ammonia toxicity tests on fish. On the basis of their literature search, median lethal concentrations of un-ionized NH_3-N at which 50 percent of the experimentally exposed fish would be expected to die (LC50) ranged from 0.3 to 0.6 mg/L for exposures of 1 day or less and 0.35 to 0.50 mg/L for exposures of 5 to 7 days. Experiments conducted by Environment Canada[11] resulted in 4 day LC50 of 0.15 mg/L (un-ionized ammonia). On the basis of this data, especially that from Environment Canada, it would appear that the effluent of both models #1 and #2, at the two higher temperatures (phases 1 and 2) would be toxic (with respect to un-ionized NH_4-N concentrations) some percentage of the time.

The findings of several studies regarding nitrite toxicity to fish were also reported by Russo and Thomann. Median lethal concentrations of NO_2-N for various species were shown to range from 0.2 to 1.5 mg/L for a 4 day test. Both models #1 and #2 average NO_2-N effluent concentrations fall within, or exceed this range, and would therefore be considered as potentially toxic and being potentially more toxic and of concern than ammonia.

TABLE 8.4 UN-IONIZED EFFLUENT NH_3-N CONCENTRATIONS
NITRIFICATION-ACTIVATED SLUDGE
MODELS #1 AND #2

Phase	Temp. (°C)	pH (range)	Percentage of Un-ionized NH_3-N* %	Effluent NH_3-N (mg/L) Total	Un-ionized
Model #1					
1	22	7.9-8.5	3.48-12.56	2.3	0.08-0.29
2	17	7.8-8.6	1.95-11.12	1.6	0.03-0.18
3	15	7.0-7.9	0.27-2.12	2.6	0.007-0.06
Model #2					
1	22	7.9-8.5	3.48-12.56	2.6	0.09-0.33
2	17	7.9-8.3	2.44-5.90	3.3	0.08-0.19
3	15	7.0-8.2	0.27-4.14	1.5	0.004-0.06

* Obtained from un-ionized NH_3-N data presented by Trussell[9].

9.0 PARTIAL MASS AND ENERGY BALANCE

A partial mass and energy balance was developed here specifically, for the peat wet carbonization project being considered for the Sunkhaze and Chemo bogs near Milford, Maine. This balance and basic data and information appear in Figure 9.1 and was developed assuming an annual production of approximately 260 000 metric tons (dry basis) of PDF per annum.

The mass and energy balance shown in Figure 9.1 for the Maine project can also be applied to the proposed Barrington, N.S. peat project by scaling numbers down by the size factor. The proposed Barrington, N.S. project will produce an estimated 8000 t/a (dry basis) of PDF and is therefore only 3.3 percent (i.e., one thirty-third) of the size of the Maine project. This factor should be used in scaling down production, energy, wastewater flow and biogas operation numbers shown on Figure 9.1.

The raw peat is pumped from the bog and is received at surge tanks located at the Wet-Carb plant. The raw peat is typically 8 percent solids and is processed at this concentration. The peat slurry is first heated in a waste heat recovery unit; in its first section, heat is recovered from the filter pressate and in the second from the wet carbonized slurry from the reactor. The partially cooled wet carbonized slurry is then dewatered (in the filter press to 50-60 percent solids) and then thermally dried and pelleted into its final form as a PDF.

The estimated processing rate is 686 wet tons per hour (55 dry tph), 24 hours per day, 250 days per annum, to produce 260 000 tons per annum of PDF.

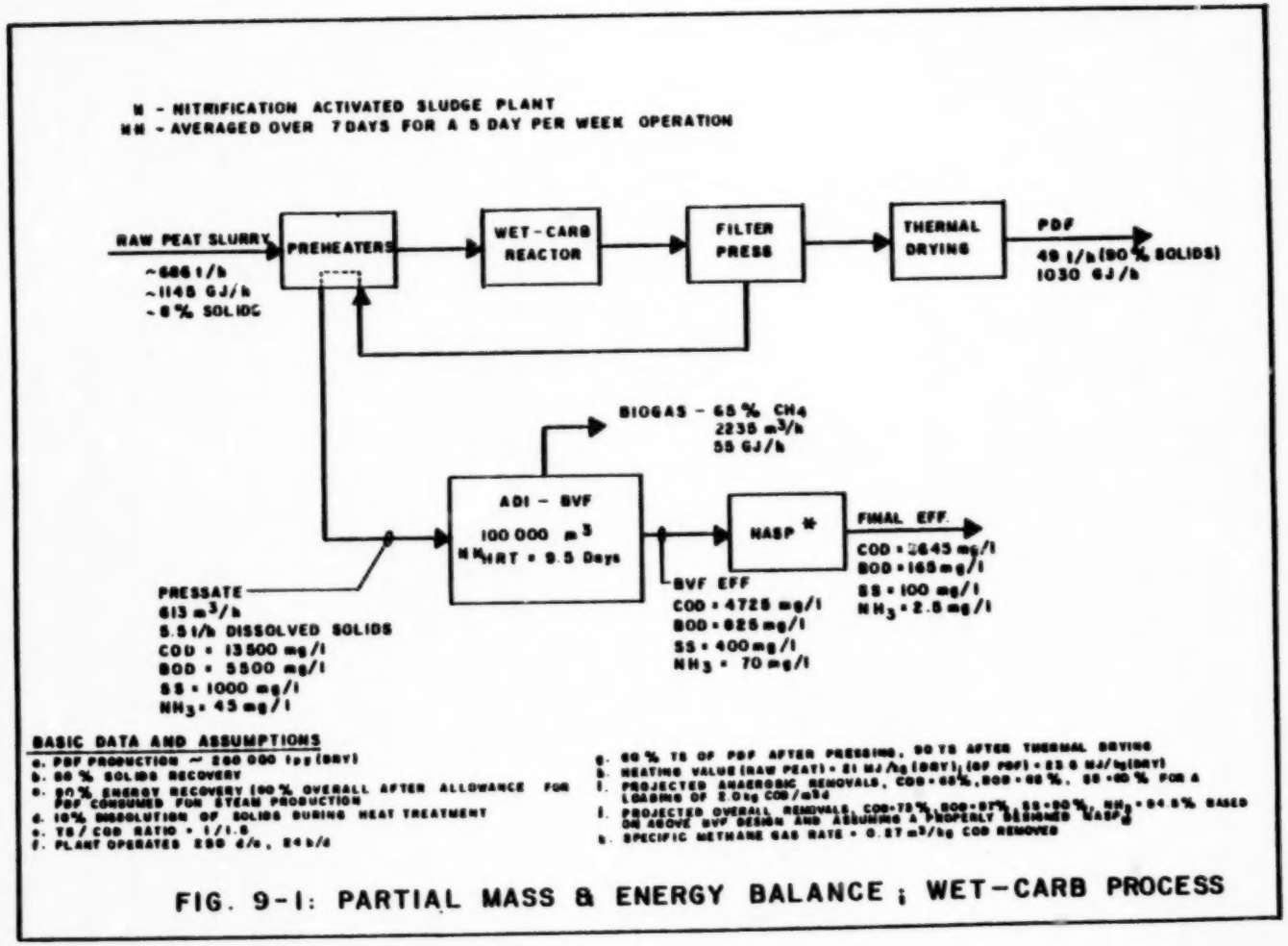

N - NITRIFICATION ACTIVATED SLUDGE PLANT
NN - AVERAGED OVER 7 DAYS FOR A 5 DAY PER WEEK OPERATION
RAW PEAT SLURRY
~686 t/h
~1148 GJ/h
~8% SOLIDS
PREHEATERS
WET-CARB REACTOR
FILTER PRESS
THERMAL DRYING
PDF
49 t/h (90% SOLIDS)
1030 GJ/h
BIOGAS - 65% CH4
2235 m3/h
55 GJ/h
ADI - BVF
100 000 m3
NNHRT = 9.5 Days
NASP *
FINAL EFF.
COD = 2645 mg/l
BOD = 165 mg/l
SS = 100 mg/l
NH3 = 2.5 mg/l
BVF EFF
COD = 4725 mg/l
BOD = 825 mg/l
SS = 400 mg/l
NH3 = 70 mg/l
PRESSATE
613 m3/h
5.5 t/h DISSOLVED SOLIDS
COD = 13500 mg/l
BOD = 5500 mg/l
SS = 1000 mg/l
NH3 = 45 mg/l
BASIC DATA AND ASSUMPTIONS
a. PDF PRODUCTION ~ 260 000 tpy (DRY)
b. 80 % SOLIDS RECOVERY
c. 80% ENERGY RECOVERY (90% OVERALL AFTER ALLOWANCE FOR PDF CONSUMED FOR STEAM PRODUCTION
d. 10% DISSOLUTION OF SOLIDS DURING HEAT TREATMENT
e. TS/COD RATIO = 1/1.8
f. PLANT OPERATES 250 d/a, 24 h/d
g. 90 % TS OF PDF AFTER PRESSING, 90 TS AFTER THERMAL DRYING
h. HEATING VALUE (RAW PEAT) = 21 MJ/kg (DRY); (OF PDF) = 23.8 MJ/kg (DRY)
i. PROJECTED ANAEROBIC REMOVALS, COD = 65%, BOD = 85 %, SS = 60 % FOR A LOADING OF 2.0 kg COD/m3d
j. PROJECTED OVERALL REMOVALS, COD=75%, BOD=97%, SS=90%, NH3 = 94.5% BASED ON ABOVE BVF DESIGN AND ASSUMING A PROPERLY DESIGNED NASP
k. SPECIFIC METHANE GAS RATE = 0.37 m3/kg COD REMOVED

FIG. 9-1: PARTIAL MASS & ENERGY BALANCE ; WET-CARB PROCESS

Solids and energy recovery factors of approximately 80 and 90 percent, respectively, were assumed. The overall net energy recovery for the process is reported to be approximately 80 percent, after allowance for consumption of the PDF for making process steam. The gross calorific values of the raw and PDF are of the order of 21 MJ and 23.6 MJ per kg (dry), respectively.

The wastewater COD was developed assuming a 10 percent dissolution of solids during heat treatment and a TS/COD ratio of 1/1.5. These figures are reasonable and the resultant COD of 13 500 mg/L agrees very well with that for the actual wastewater. The other parameters were estimated directly from the actual peat pressate characteristics (reference Table 4.2). The volume of wastewater (613 m^3/h) was estimated assuming that the filter presses would achieve a cake of approximately 60 percent solids.

The methane and biogas production rates were estimated assuming 65 percent COD removal, anaerobically, a methane concentration of 65 percent by volume and a unit generation rate of 0.27 m^3 methane per kg COD destroyed (as established in this study). The volume and energy content of the biogas were calculated to be 2235 m^3/h and 55 GJ/h, respectively. As a percentage of the energy content of the PDF (i.e., 1030 GJ/h) the biogas contains approximately 5.5 percent. Therefore, in terms of the overall balance of the wet-carb process, the anaerobic treatment system improves this balance significantly while improving upon a rather serious environmental problem.

The total energy credit for anaerobic treatment is not fully developed here and cannot be fully appreciated until one compares anaerobic to conventional forms of aerobic treatment.

10.0 ECONOMIC ANALYSES

The capital and annual operating and maintenance costs appear below for both the Barrington and Maine peat projects. These costs are developed in detail in Appendices I and J, respectively. These costs do not include any allowance for aerobic treatment except for the O&M costs, which include sufficient allowance for operators to cover both anaerobic and aerobic.

The design criteria and assumptions upon which these costs were developed appear in Appendix H; based upon these criteria, BVFs of 3000 m^3 and 100 000 m^3 (2 @ 50 000) reactive volume would be required for the Barrington and Maine peat projects, respectively.

ADI-BVF Capital and O&M Costs Summary

	Barrington	Maine
Capital Costs	$ 667 000	$5 187 000
O&M Costs	$ 215 000	$ 447 000

From the above table it is quite apparent that economy-of-scale plays a very important factor in the cost of the BVF anaerobic system.

The above capital costs include an engineering allowance sufficient to cover preliminary, detailed design, construction and inspection, commissioning and startup services.

REFERENCES

1. "Anaerobic Fermentation of ORF WETOX^{R} Pressate for the Production of Methane," National Research Council of Canada, DSS Report No. 02SX.31926-3-0105.

2. Standard Methods for the Examination of Water and Wastewater, 15th Edition, American Public Health Association, New York (1980).

3. "Analysis of Spent Sulphite Liquor," TAPPI Standard Method, T629 05-53.

4. DiLallo, R. and Albertson, O.E., "Volatile Acids by Direct Titration," JWPCF, 33, 4 (1961).

5. "Instrument Manual," Fisher Orsat Gas Apparatus, Cat. No. 10-605-10-623, Instrument Division, Fisher Scientific Company, 711 Forbes Avenue, Pittsburg, Penn.

6. Lesperance, T.W., "A Generalized Approach to Activated Sludge," Journal Water Works and Wastes Engineering, (1965).

7. Lu, F., et al., "Nitrification of Anaerobically Treated Coal Gasifier Effluent." Journal Water Pollution Control Federation, 56, 9, pp 1050-1058, (1984).

8. Lee, S., and Naimie, H., "The Mechanism of Ammonia Removal in a Single Stage Nitrification System Having Long HRT." Paper prepared for Merck Sharp and Dohme Research Laboratories, Rahway, New Jersey.

9. Trussell, R.P., "The Percent Un-ionized Ammonia in Aqueous Ammonia Solutions at Different pH Levels and Temperatures." Journal Fisheries Research Board of Canada, 29, 10, pp 1505-1507, (1972).

10. Russo, R.C., and Thomann, R.V., "Ammonia and Nitrite Toxicity to Fishes." Proceedings of the First and Second USA/USSR Symposium on the Effects of Pollutants Upon Aquatic Ecosystems. Section F, pp 75-82, EPA-600/3-78-076.

11. Correspondence with Environment Canada, Air and Water Branch (1985).

12. Mines, R.O., and Sherrard, J.H., "Activated Sludge Treatment of a High Strength Nitrogenous Waste." Paper presented at the 1985 Purdue University Industrial Waste Conference.

APPENDIX A

RAW PEAT PROCESSING CONDITIONS

BOD	SUNKHAZE	CHEMO
Average T, °C	211	208
Average P, kPa	2740	2760
Residence Time, Min.	37	40

APPENDIX B

BVF #1 INFLUENT AND EFFLUENT DATA

TABLE B.1 - COD, BOD, SS, VSS DATA : BVF # 1

DATE (from)	DATE (to)	DAYS (from)	DAYS (to)	INFLUENT COD (mg/l)	INFLUENT BOD (mg/l)	INFLUENT SS (mg/l)	INFLUENT VSS (mg/l)	EFFLUENT COD (mg/l)	EFFLUENT BOD (mg/l)	EFFLUENT SS (mg/l)	EFFLUENT VSS (mg/l)
85 1 2	85 1 7	1	6	2750	NA	140	140	1200	NA	157	90
85 1 8	85 1 14	7	13	4800	NA	305	305	1050	NA	113	113
85 1 15	85 1 21	14	20	6700	NA	540	490	2200	NA	140	78
85 1 22	85 1 28	21	27	11600	NA	696	678	1700	NA	44	34
85 1 29	85 2 4	28	34	12900	4650	430	290	3000	222	170	147
85 2 5	85 2 11	35	41	14600	5310	912	852	4100	540	166	152
85 2 12	85 2 18	42	48	14900	5050	1347	1253	4300	668	187	173
85 2 19	85 2 25	49	55	12400	5440	667	593	4900	1140	224	184
85 2 26	85 3 4	56	62	13900	5890	615	567	4900	1180	257	248
85 3 5	85 3 11	63	69	14100	4640	609	552	5700	930	265	250
85 3 12	85 3 18	70	76	15000	4640	1447	1353	5500	743	431	365
85 3 19	85 3 25	77	83	14800	4770	1284	1168	5000	601	250	230
85 3 26	85 4 1	84	90	15100	4980	2675	2470	5500	607	339	261
85 4 2	85 4 8	91	97	13600	3770	505	467	5050	709	340	330
85 4 9	85 4 15	98	104	14400	5100	920	780	5700	673	500	478
85 4 16	85 4 22	105	111	12200	4900	376	376	5100	850	402	370
85 4 23	85 4 29	112	118	13400	4310	635	625	5100	606	318	206
85 4 30	85 5 6	119	125	9700	4180	543	465	4400	526	364	342
85 5 7	85 5 13	126	132	14000	4820	1486	1430	4400	465	476	476
85 5 14	85 5 17	133	136	19000	7815	974	902	5400	753	454	421

TABLE B.2 - COD, BOD, SS, VSS REMOVALS & LOADINGS : BVF # 1

DATE (from)	DATE (to)	DAYS (from)	DAYS (to)	REMOVALS COD (%)	REMOVALS BOD (%)	REMOVALS SS (%)	REMOVALS VSS (%)	FEED FLOW (l/d)	LOADINGS COD (kg/m3 d)	LOADINGS BOD (kg/m3 d)	LOADINGS SS (kg/m3 d)	LOADINGS VSS (kg/m3 d)
85 1 2	85 1 7	1	6	56.4	NA	0.0	35.7	0.56	0.24	NA	0.01	0.01
85 1 8	85 1 14	7	13	78.1	NA	63.0	63.0	0.59	0.44	NA	0.03	0.03
85 1 15	85 1 21	14	20	67.2	NA	74.1	84.1	0.61	0.64	NA	0.05	0.05
85 1 22	85 1 28	21	27	85.3	NA	93.7	95.0	0.63	1.14	NA	0.07	0.07
85 1 29	85 2 4	28	34	76.7	95.2	60.5	49.3	0.40	0.81	0.29	0.03	0.02
85 2 5	85 2 11	35	41	71.9	89.8	81.8	82.2	0.65	1.48	0.54	0.09	0.09
85 2 12	85 2 18	42	48	71.1	86.8	86.1	86.2	0.69	1.61	0.54	0.15	0.14
85 2 19	85 2 25	49	55	60.5	79.0	66.4	69.0	0.63	1.22	0.54	0.07	0.06
85 2 26	85 3 4	56	62	64.7	80.0	58.2	56.3	0.96	2.09	0.88	0.09	0.09
85 3 5	85 3 11	63	69	59.6	80.0	56.5	54.7	1.16	2.56	0.84	0.11	0.10
85 3 12	85 3 18	70	76	63.3	84.0	70.2	73.0	0.95	2.23	0.69	0.21	0.20
85 3 19	85 3 25	77	83	66.2	87.4	80.5	80.3	0.77	1.78	0.57	0.15	0.14
85 3 26	85 4 1	84	90	63.6	87.8	87.3	89.4	0.94	2.22	0.73	0.39	0.36
85 4 2	85 4 8	91	97	62.9	81.2	32.7	29.3	1.00	2.13	0.59	0.08	0.07
85 4 9	85 4 15	98	104	60.4	86.8	45.7	38.7	0.96	2.16	0.77	0.14	0.12
85 4 16	85 4 22	105	111	58.2	82.7	0.0	1.6	1.00	1.91	0.77	0.06	0.06
85 4 23	85 4 29	112	118	61.9	85.9	49.9	67.0	0.96	2.01	0.65	0.10	0.09
85 4 30	85 5 6	119	125	54.6	87.4	33.0	26.5	0.93	1.41	0.61	0.08	0.07
85 5 7	85 5 13	126	132	68.6	90.4	68.0	66.7	0.88	1.93	0.66	0.20	0.20
85 5 14	85 5 17	133	136	71.6	90.4	53.4	53.3	0.86	2.55	1.05	0.13	0.12

TABLE B.3 - pH, VA, ALK CONCENTRATIONS : BVF # 1

DATE	DAY	INFLUENT			EFFLUENT		
		pH	VA (mg/l)	ALK (mg/l)	pH	VA (mg/l)	ALK (mg/l)
85 1 3	2	7.5	330	1659	8.0	108	2769
85 1 7	6	8.0	338	1650	8.3	130	2450
85 1 10	9	NA	NA	NA	8.0	120	3000
85 1 15	14	6.4	NA	1100	7.0	360	2250
85 1 17	16	NA	NA	NA	8.0	180	2800
85 1 21	20	8.0	NA	1550	7.5	300	3100
85 1 24	23	NA	NA	NA	7.5	261	2270
85 1 28	27	5.6	780	400	7.0	368	2080
85 2 1	31	NA	NA	NA	7.4	312	1920
85 2 4	34	5.1	1373	400	8.0	360	2050
85 2 7	37	NA	NA	NA	7.7	345	1900
85 2 11	41	4.9	NA	270	6.9	512	1844
85 2 14	44	NA	NA	NA	7.3	435	1850
85 2 18	48	4.9	NA	350	7.0	555	1800
85 2 21	51	NA	NA	NA	7.1	540	1700
85 2 25	55	4.6	1168	200	8.1	488	2000
85 2 28	58	NA	NA	NA	6.9	608	1700
85 3 4	62	4.6	NA	200	6.8	780	1650
85 3 7	65	NA	NA	NA	6.7	810	1700
85 3 11	69	5.7	NA	700	7.0	870	2000
85 3 14	72	NA	NA	NA	7.5	840	2150
85 3 18	76	6.5	NA	800	7.4	765	2200
85 3 21	79	NA	NA	NA	7.4	608	2200
85 3 25	83	5.8	NA	650	7.4	555	2200
85 3 29	87	NA	NA	NA	7.1	585	1900
85 4 1	90	4.8	NA	250	7.0	653	1900
85 4 4	93	NA	NA	NA	7.0	555	1700
85 4 8	97	4.5	NA	200	6.9	615	1650
85 4 11	100	NA	NA	NA	7.0	525	1600
85 4 15	104	4.5	NA	100	7.2	525	1500
85 4 18	107	4.2	870	0	6.8	551	1370
85 4 22	111	5.1	1310	300	7.0	540	1450
85 4 25	114	NA	NA	NA	6.9	525	1450
85 4 29	118	4.7	1020	150	6.9	469	1302
85 5 2	121	NA	NA	NA	7.2	454	2267
85 5 6	125	5.0	975	750	7.1	363	1935
85 5 9	128	NA	NA	NA	7.0	603	1304
85 5 13	132	5.5	924	473	7.1	452	2038
85 5 16	135	NA	NA	NA	7.0	375	1100

APPENDIX C

OPERATIONS AND LOADING DATA: NITRIFICATION-ACTIVATED SLUDGE MODELS #1 AND #2

TABLE C.1 OPERATIONAL DATA : NITRIFICATION - ACTIVATED SLUDGE MODEL # 1

DATE	DAY	Q (L/d)	HRT (d)	TEMP (C)	MLSS (mg/L)	MLVSS (mg/L)	MLVSS/MLSS
85 2 26	1	NA	NA	22.0	NA	NA	NA
85 2 27	2	0.45	2.18	23.0	NA	NA	NA
85 3 1	4	0.44	2.23	23.0	2376	1442	0.61
85 3 4	7	0.49	2.00	19.0	3125	1959	0.63
85 3 6	9	0.53	1.85	23.0	NA	NA	NA
85 3 8	11	0.44	2.23	25.0	NA	NA	NA
85 3 11	14	0.37	2.65	22.0	3894	3174	0.81
85 3 13	16	0.52	1.88	23.0	NA	NA	NA
85 3 15	18	0.62	1.58	21.0	NA	NA	NA
85 3 18	21	0.63	1.56	22.0	3872	3385	0.87
85 3 20	23	0.49	2.00	23.0	NA	NA	NA
85 3 22	25	0.48	2.04	17.0	NA	NA	NA
AVG		0.50	2.02	21.92	3317	2490	
STD DEV		0.07	0.30	2.02	625	814	
85 3 25	28	0.46	2.13	22.0	2512	1050	0.42
85 3 27	30	0.51	1.92	14.0	NA	NA	NA
85 3 29	32	0.32	3.06	15.0	NA	NA	NA
85 4 1	35	0.50	1.96	17.5	2825	1576	0.56
85 4 3	37	0.53	1.85	15.0	NA	NA	NA
85 4 8	42	0.53	1.85	18.5	2861	1423	0.50
85 4 10	44	0.54	1.81	18.5	NA	NA	NA
85 4 12	46	0.51	1.92	16.5	NA	NA	NA
85 4 15	49	0.52	1.88	18.0	2464	2232	0.91
85 4 17	51	0.53	1.85	16.5	NA	NA	NA
85 4 19	53	0.50	1.96	17.5	3024	2524	0.83
85 4 22	56	0.46	2.13	17.5	3050	2625	0.86
85 4 24	58	0.48	2.04	17.5	NA	NA	NA
85 4 26	60	0.51	1.92	16.0	3100	2760	0.89
AVG		0.49	2.02	17.14	2834	2027	
STD DEV		0.05	0.30	1.88	237	622	
85 4 29	63	0.45	2.18	13.5	3033	2800	0.92
85 5 1	65	0.51	1.92	15.5	NA	NA	NA
85 5 3	67	0.48	2.04	15.0	3382	3000	0.89
85 5 6	70	0.44	2.23	16.0	3750	2525	0.67
85 5 8	72	0.51	1.92	16.0	NA	NA	NA
85 5 10	74	0.49	2.00	17.5	NA	NA	NA
85 5 13	77	0.47	2.09	14.0	NA	NA	NA
85 5 15	79	0.50	1.96	14.5	3800	3383	0.89
85 5 17	81	0.45	2.18	14.5	3344	2856	0.85
AVG		0.48	2.06	15.17	3462	2913	
STD DEV		0.03	0.11	1.15	283	281	

TABLE C.2 OPERATIONAL DATA : NITRIFICATION - ACTIVATED SLUDGE MODEL # 2

DATE	DAY	Q	HRT	TEMP	MLSS	MLVSS	MLVSS/MLSS
		(L/d)	(d)	(C)	(mg/L)	(mg/L)	
85 2 26	1	NA	NA	22.0	NA	NA	NA
85 2 27	2	0.49	1.12	23.0	NA	NA	NA
85 3 1	4	0.47	1.17	23.0	2097	1504	0.72
85 3 4	7	0.51	1.08	19.0	2334	1268	0.54
85 3 6	9	0.60	0.92	23.0	NA	NA	NA
85 3 8	11	0.47	1.17	25.0	NA	NA	NA
85 3 11	14	0.43	1.28	22.0	4148	3777	0.91
85 3 13	16	0.51	1.08	23.0	NA	NA	NA
85 3 15	18	0.58	0.95	21.0	NA	NA	NA
85 3 18	21	0.68	0.81	22.0	3759	3264	0.87
85 3 20	23	0.53	1.04	23.0	NA	NA	NA
85 3 22	25	0.48	1.15	17.0	NA	NA	NA
AVG		0.52	1.07	21.92	3085	2453	
STD DEV		0.07	0.13	2.02	884	1086	
85 3 25	28	0.49	1.12	22.0	3461	2035	0.59
85 3 27	30	0.55	1.00	22.0	NA	NA	NA
85 3 29	32	0.35	1.57	15.0	NA	NA	NA
85 4 1	35	0.50	1.10	17.5	3504	2120	0.60
85 4 3	37	0.59	0.93	15.0	NA	NA	NA
85 4 8	42	0.57	0.96	18.5	3560	2213	0.62
85 4 10	44	0.55	1.00	18.5	NA	NA	NA
85 4 12	46	0.57	0.96	15.5	NA	NA	NA
85 4 15	49	0.55	1.00	18.0	3568	2750	0.77
85 4 17	51	0.54	1.02	16.0	NA	NA	NA
85 4 19	53	0.50	1.10	17.0	1657	1320	0.80
85 4 22	56	0.50	1.10	17.5	3083	2861	0.93
85 4 24	58	0.53	1.04	17.5	NA	NA	NA
85 4 26	60	0.57	0.96	16.0	4467	4033	0.90
AVG		0.53	1.06	17.57	3329	2476	
STD DEV		0.06	0.15	2.14	785	790	
85 4 29	63	0.45	1.22	13.5	4033	3500	0.87
85 5 1	65	0.58	0.95	15.0	NA	NA	NA
85 5 3	67	0.50	1.10	15.0	3344	3031	0.91
85 5 6	70	0.48	1.15	16.0	4368	3421	0.78
85 5 8	72	0.52	1.06	16.0	NA	NA	NA
85 5 10	74	0.30	1.83	16.5	NA	NA	NA
85 5 13	77	0.51	1.08	13.0	2746	2408	0.88
85 5 15	79	0.50	1.10	13.5	1990	1750	0.88
85 5 17	81	0.48	1.15	14.0	1576	1312	0.83
AVG		0.48	1.18	14.72	3010	2570	
STD DEV		0.07	0.24	1.20	1014	825	

TABLE C.3 LOADING DATA (TKN,NH3-N,COD,BOD) :
NITRIFICATION - ACTIVATED SLUDGE MODEL # 1

DATE	DAY	MODEL LOADINGS			
		TKN	NH3-N	COD	BOD
		(Kg/Kg MLVSS/d)			
85 2 26	1	NA	NA	NA	NA
85 2 27	2	0.016	0.005	0.738	0.039
85 3 1	4	0.020	0.007	0.793	0.157
85 3 4	7	0.025	0.009	0.843	0.147
85 3 6	9	0.028	0.010	0.988	0.197
85 3 8	11	0.036	0.009	0.920	0.098
85 3 11	14	0.021	0.008	0.773	0.072
85 3 13	16	0.026	0.011	1.002	0.104
85 3 15	18	0.036	0.013	1.220	0.082
85 3 18	21	0.044	0.015	1.317	0.113
85 3 20	23	0.030	0.011	0.994	0.080
85 3 22	25	0.025	0.011	0.866	0.048
AVG		0.028	0.010	0.950	0.103
STD DEV		0.008	0.003	0.174	0.046
85 3 25	28	0.030	0.014	0.973	0.046
85 3 27	30	0.035	0.016	1.155	0.092
85 3 29	32	0.022	0.010	0.733	0.043
85 4 1	35	0.039	0.015	1.158	0.063
85 4 3	37	0.035	0.017	1.267	0.084
85 4 8	42	0.035	0.015	1.147	0.072
85 4 10	44	0.037	0.018	1.291	0.133
85 4 12	46	0.038	0.015	1.258	0.094
85 4 15	49	0.035	0.014	1.204	0.075
85 4 17	51	0.043	0.017	1.334	0.124
85 4 19	53	0.037	0.017	1.158	0.083
85 4 22	56	0.041	0.014	1.158	0.098
85 4 24	58	0.039	0.016	1.112	0.117
85 4 26	60	0.041	0.016	1.155	0.088
AVG		0.036	0.015	1.150	0.087
STD DEV		0.005	0.002	0.144	0.026
85 4 29	63	0.025	0.010	0.709	0.047
85 5 1	65	0.026	0.012	0.875	0.072
85 5 3	67	0.025	0.010	0.799	0.064
85 5 6	70	0.020	0.008	0.732	0.049
85 5 8	72	0.018	0.009	0.804	0.056
85 5 10	74	0.020	0.009	0.721	0.032
85 5 13	77	0.018	0.007	0.626	0.036
85 5 15	79	0.023	0.010	0.771	0.055
85 5 17	81	0.021	0.009	0.670	0.039
AVG		0.022	0.009	0.745	0.050
STD DEV		0.003	0.001	0.071	0.012

TABLE C.4 LOADING DATA (TKN,NH3-N,COD,BOD) :
NITRIFICATION - ACTIVATED SLUDGE MODEL # 2

DATE	DAY	MODEL LOADINGS			
		TKN	NH3-N	COD	BOD
		(Kg/Kg MLVSS/d)			
85 2 26	1	NA	NA	NA	NA
85 2 27	2	0.032	0.010	1.453	0.076
85 3 1	4	0.039	0.013	1.533	0.304
85 3 4	7	0.047	0.016	1.588	0.276
85 3 6	9	0.058	0.020	2.023	0.404
85 3 8	11	0.069	0.017	1.777	0.190
85 3 11	14	0.045	0.017	1.625	0.152
85 3 13	16	0.047	0.020	1.777	0.184
85 3 15	18	0.061	0.023	2.064	0.138
85 3 18	21	0.086	0.029	2.571	0.220
85 3 20	23	0.059	0.022	1.945	0.157
85 3 22	25	0.045	0.021	1.565	0.086
AVG		0.053	0.019	1.811	0.199
STD DEV		0.014	0.005	0.310	0.093
85 3 25	28	0.046	0.021	1.511	0.071
85 3 27	30	0.055	0.025	1.817	0.145
85 3 29	32	0.035	0.016	1.169	0.068
85 4 1	35	0.056	0.022	1.689	0.093
85 4 3	37	0.058	0.027	2.058	0.136
85 4 8	42	0.055	0.024	1.800	0.113
85 4 10	44	0.055	0.026	1.918	0.197
85 4 12	46	0.062	0.025	2.051	0.154
85 4 15	49	0.053	0.022	1.858	0.116
85 4 17	51	0.065	0.026	1.983	0.184
85 4 19	53	0.054	0.024	1.689	0.122
85 4 22	56	0.064	0.022	1.836	0.155
85 4 24	58	0.063	0.026	1.790	0.188
85 4 26	60	0.067	0.026	1.884	0.144
AVG		0.056	0.024	1.790	0.135
STD DEV		0.008	0.003	0.222	0.039
85 4 29	63	0.050	0.020	1.433	0.095
85 5 1	65	0.059	0.027	2.011	0.165
85 5 3	67	0.052	0.022	1.680	0.135
85 5 6	70	0.045	0.019	1.613	0.108
85 5 8	72	0.037	0.018	1.655	0.116
85 5 10	74	0.025	0.012	0.891	0.039
85 5 13	77	0.040	0.016	1.371	0.079
85 5 15	79	0.047	0.019	1.556	0.111
85 5 17	81	0.046	0.020	1.443	0.084
AVG		0.045	0.019	1.517	0.104
STD DEV		0.009	0.004	0.284	0.034

APPENDIX D

NITROGEN DATA:
NITRIFICATION-ACTIVATED SLUDGE
MODELS #1 AND #2

TABLE D.1 INFLUENT AND EFFLUENT NITROGEN DATA :
NITRIFICATION - ACTIVATED SLUDGE MODEL # 1

DATE	DAY	INFLUENT TKN	INFLUENT NH3-N	INFLUENT NO3-N	INFLUENT NO2-N	EFFLUENT TKN	EFFLUENT NH3-N	EFFLUENT NO3-N	EFFLUENT NO2-N
		(mg/L)							
85 2 26	1	NA	NA	NA	*	NA	NA	NA	NA
85 2 27	2	88.9	26.9	2.3	0.1	53.4	1.8	36.8	1.0
85 3 1	4	111	38.3	1.9	0.1	60.5	6.8	18.2	4.0
85 3 4	7	124	42.8	1.8	0.1	70.3	17.1	24.8	0.1
85 3 6	9	131	45.3	1.8	0.1	68.5	4.1	1.9	7.3
85 3 8	11	198	49.0	2.0	0.1	65.9	1.7	51.1	1.2
85 3 11	14	141	53.0	1.5	0.1	69.6	3.1	44.0	2.1
85 3 13	16	124	53.0	2.4	0.1	61.3	2.4	46.9	1.2
85 3 15	18	142	52.5	2.1	0.1	64.7	3.6	38.7	1.3
85 3 18	21	170	57.6	2.5	0.1	71.6	3.7	48.4	1.4
85 3 20	23	151	56.5	2.7	0.1	76.4	1.3	71.8	0.6
85 3 22	25	127	58.3	2.6	0.1	71.3	<0.5	71.4	0.8
AVG		137	48.5	2.1	0.1				
STD DEV		28	9.1	0.4	0.0				
85 3 25	28	129	58.8	2.2	0.1	79.3	14.2	39.4	4.5
85 3 27	30	136	62.9	3.6	0.1	94.1	26.4	21.1	3.1
85 3 29	32	136	61.6	2.7	0.1	117.0	44.4	2.7	<0.1
85 4 1	35	153	59.0	2.7	0.1	99.9	44.2	8.9	4.8
85 4 3	37	133	62.1	2.7	0.1	95.8	24.5	28.7	10.5
85 4 8	42	132	58.0	3.5	0.1	92.3	17.6	22.1	13.3
85 4 10	44	135	64.7	3.6	0.1	76.7	2.7	59.7	7.2
85 4 12	46	148	58.9	4.1	0.1	72.5	1.0	64.2	0.7
85 4 15	49	132	55.1	5.8	0.1	79.7	2.3	68.5	0.9
85 4 17	51	163	65.1	4.4	0.1	78.4	1.4	85.5	0.5
85 4 19	53	147	65.9	4.3	0.1	79.8	1.8	79.8	0.8
85 4 22	56	175	59.5	3.4	0.1	91.7	1.9	77.2	1.8
85 4 24	58	162	66.9	4.0	0.1	84.8	0.7	88.2	0.9
85 4 26	60	161	62.5	3.8	0.1	81.3	1.3	90.5	0.6
AVG		146	61.5	3.6	0.1				
STD DEV		14	3.3	0.9	0.0				
85 4 29	63	158	64.2	3.3	0.1	81.5	2.1	79.4	1.9
85 5 1	65	144	65.7	3.5	0.1	83.0	5.9	61.5	1.3
85 5 3	67	148	61.5	3.1	0.1	79.0	<0.5	72.3	0.5
85 5 6	70	133	55.1	3.2	0.1	76.9	0.8	68.5	0.8
85 5 8	72	101	48.3	3.0	0.1	83.4	3.5	65.3	0.7
85 5 10	74	119	54.5	3.0	0.1	74.0	9.0	40.8	2.4
85 5 13	77	112	43.7	2.5	0.1	87.3	22.7	15.9	2.3
85 5 15	79	133	55.0	2.6	0.1	89.4	30.4	14.0	2.3
85 5 17	81	135	59.5	2.7	0.1	95.0	29.9	17.1	3.3
AVG		131	56.4	3.0	0.1				
STD DEV		17	6.8	0.3	0.0				

* NO2-N values measured as < 0.1 mg/L but assumed as 0.1 for calculation purposes

TABLE D.2 INFLUENT AND EFFLUENT NITROGEN DATA :
NITRIFICATION - ACTIVATED SLUDGE MODEL # 2

DATE	DAY	INFLUENT TKN	INFLUENT NH3-N	INFLUENT NO3-N	INFLUENT NO2-N	EFFLUENT TKN	EFFLUENT NH3-N	EFFLUENT NO3-N	EFFLUENT NO2-N
		(mg/L)							
85 2 26	1	NA	NA	NA	*	NA	NA	NA	NA
85 2 27	2	88.9	26.9	2.3	0.1	51.5	0.8	32.8	1.0
85 3 1	4	111	38.3	1.9	0.1	56.5	4.6	2.0	2.8
85 3 4	7	124	42.8	1.8	0.1	83.5	27.0	20.5	0.1
85 3 6	9	131	45.3	1.8	0.1	93.0	24.2	1.9	0.2
85 3 8	11	198	49.0	2.0	0.1	76.9	17.1	4.0	2.1
85 3 11	14	141	53.0	1.5	0.1	81.0	13.4	5.8	2.4
85 3 13	16	124	53.0	2.4	0.1	77.0	2.7	43.5	7.1
85 3 15	18	142	52.5	2.1	0.1	69.3	5.6	43.5	4.6
85 3 18	21	170	57.6	2.5	0.1	88.6	26.1	5.5	1.9
85 3 20	23	151	56.5	2.7	0.1	77.2	2.0	59.0	2.5
85 3 22	25	127	58.3	2.6	0.1	75.3	<0.5	66.9	1.3
AVG		137	48.5	2.1	0.1				
STD DEV		28	9.1	0.4	0.0				
85 3 25	28	129	58.8	2.2	0.1	71.7	2.0	57.7	4.7
85 3 27	30	136	62.9	3.6	0.1	72.4	2.3	70.7	0.5
85 3 29	32	136	61.6	2.7	0.1	118.0	33.0	14.9	2.5
85 4 1	35	153	59.0	2.7	0.1	78.4	33.0	45.5	3.3
85 4 3	37	133	62.1	2.7	0.1	69.8	1.3	63.2	1.2
85 4 8	42	132	58.0	3.5	0.1	74.4	7.2	48.9	1.7
85 4 10	44	135	64.7	3.6	0.1	81.7	1.3	71.6	0.6
85 4 12	46	148	58.9	4.1	0.1	65.0	2.1	56.0	0.7
85 4 15	49	132	55.1	5.8	0.1	98.2	3.3	53.3	1.9
85 4 17	51	163	65.1	4.4	0.1	79.2	2.0	66.7	0.9
85 4 19	53	147	65.9	4.3	0.1	77.3	6.1	47.1	2.2
85 4 22	56	175	59.5	3.4	0.1	83.8	7.4	48.4	2.9
85 4 24	58	162	66.9	4.0	0.1	82.4	1.0	77.7	1.1
85 4 26	60	161	62.5	3.8	0.1	76.9	1.1	74.0	0.9
AVG		146	61.5	3.6	0.1				
STD DEV		14	3.3	0.9	0.0				
85 4 29	63	158	64.2	3.3	0.1	91.1	6.7	57.6	2.8
85 5 1	65	144	65.7	3.5	0.1	93.5	15.9	42.6	2.6
85 5 3	67	148	61.5	3.1	0.1	81.4	<0.5	69.3	0.7
85 5 6	70	133	55.1	3.2	0.1	91.4	0.6	64.6	1.5
85 5 8	72	101	48.3	3.0	0.1	82.7	1.0	81.0	0.8
85 5 10	74	119	54.5	3.0	0.1	NA	NA	NA	NA
85 5 13	77	112	43.7	2.5	0.1	81.8	4.2	51.1	1.8
85 5 15	79	133	55.0	2.6	0.1	79.2	1.0	70.5	0.9
85 5 17	81	135	59.5	2.7	0.1	87.7	1.6	76.4	1.3
AVG		131	56.4	3.0	0.1				
STD DEV		17	6.8	0.3	0.0				

* NO2-N values measured as < 0.1 mg/L but assumed as 0.1 for calculation purposes

APPENDIX E

CARBONACEOUS AND SOLIDS DATA: NITRIFICATION-ACTIVATED SLUDGE MODELS #1 AND #2

TABLE E.1 CARBONACEOUS AND SOLIDS DATA : NITRIFICATION - ACTIVATED SLUDGE MODEL # 1

DATE	DAY	INFLUENT pH	INFLUENT ALK	INFLUENT COD	INFLUENT BOD	INFLUENT SS	INFLUENT VSS	MODEL pH	EFFLUENT ALK	EFFLUENT COD	EFFLUENT BOD	EFFLUENT SS	EFFLUENT VSS
		(mg/L)							(mg/L)				
85 2 26	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
85 2 27	2	NA	1450	4000	210	67	67	8.1	1270	3200	82	26	26
85 3 1	4	8.0	1500	4400	873	176	176	8.1	1400	3400	55	24	23
85 3 4	7	8.0	1600	4200	730	244	219	8.2	1500	3400	79	55	51
85 3 6	9	8.0	1450	4550	908	346	296	8.3	1330	3550	183	106	81
85 3 8	11	7.8	1500	5100	544	591	500	8.2	1300	3450	115	84	62
85 3 11	14	7.7	1550	5100	478	353	308	7.9	1350	3750	107	93	62
85 3 13	16	NA	1800	4700	487	235	227	NA	1400	3550	100	112	100
85 3 15	18	8.2	1800	4800	322	573	518	8.3	1500	3600	108	146	121
85 3 18	21	8.2	2000	5100	437	615	449	8.3	1500	3550	142	118	108
85 3 20	23	8.1	1950	4950	399	475	389	8.5	1400	3400	72	38	33
85 3 22	25	8.1	2050	4400	242	149	139	8.5	1650	3450	65	43	33
AVG			1695	4664	512	348	299		1418	3482	101	77	64
STD DEV			220	367	225	183	143		106	135	35	40	33
85 3 25	28	8.2	2000	4200	197	126	115	8.4	1700	3550	71	40	31
85 3 27	30	8.0	2000	4500	360	207	148	8.6	1820	3800	135	100	80
85 3 29	32	8.0	2100	4550	265	187	130	8.4	2100	4100	200	190	135
85 4 1	35	8.3	2150	4600	252	360	235	8.5	2000	4350	110	156	124
85 4 3	37	8.0	1900	4750	315	165	148	8.4	1800	4000	81	58	58
85 4 8	42	8.0	2000	4300	269	113	113	8.4	1800	3950	125	71	71
85 4 10	44	7.9	1700	4750	489	178	170	8.5	1500	3900	90	42	42
85 4 12	46	8.0	1750	4900	368	293	268	8.3	1400	4000	58	32	32
85 4 15	49	8.0	1700	4600	288	208	148	8.1	1300	3900	146	224	164
85 4 17	51	7.9	1650	5000	465	404	348	8.0	1200	3500	116	118	97
85 4 19	53	7.9	1650	4600	331	132	130	7.8	1200	3900	125	200	178
85 4 22	56	8.2	1800	5000	423	756	606	8.2	1250	3600	114	138	117
85 4 24	58	NA	NA	4600	483	408	408	NA	NA	3600	99	123	123
85 4 25	59	7.9	1600	NA	NA	NA	NA	8.0	1200	NA	NA	NA	NA
85 4 26	60	8.0	1450	4500	343	333	333	7.9	1000	3500	81	78	78
AVG			1818	4632	346	276	236		1519	3832	111	112	95
STD DEV			201	226	88	166	139		334	244	35	61	45
85 4 29	63	8.0	1450	4500	298	318	307	7.9	1050	4000	92	76	76
85 5 1	65	7.3	1300	4900	403	336	318	7.9	1100	3750	123	105	105
85 5 3	67	7.8	1450	4750	382	232	220	7.6	1450	3700	157	176	176
85 5 6	70	8.2	1400	4750	318	150	150	7.7	1150	3900	140	43	43
85 5 8	72	7.6	1520	4500	314	167	167	7.4	1070	4100	219	214	214
85 5 10	74	7.8	1350	4200	185	188	188	7.4	1050	3750	63	75	75
85 5 13	77	8.6	1200	3800	220	183	183	7.9	750	3600	83	120	120
85 5 15	79	7.1	1200	4400	314	262	262	7.0	1150	3800	86	122	114
85 5 17	81	7.8	1300	4250	247	228	214	7.4	1450	3550	132	110	92
AVG			1352	4450	298	229	223		1136	3794	122	116	113
STD DEV			106	319	67	62	57		202	169	45	49	50

TABLE E.2 CARBONACEOUS AND SOLIDS DATA : NITRIFICATION - ACTIVATED SLUDGE MODEL # 2

DATE	DAY	INFLUENT pH	INFLUENT ALK	INFLUENT COD	INFLUENT BOD	INFLUENT SS	INFLUENT VSS	MODEL pH	EFFLUENT ALK	EFFLUENT COD	EFFLUENT BOD	EFFLUENT SS	EFFLUENT VSS
		(mg/L)							(mg/L)				
85 2 26	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
85 2 27	2	NA	1450	4000	210	67	67	8.1	1250	2950	91	45	38
85 3 1	4	8.0	1500	4400	873	176	176	8.0	1500	3300	50	17	17
85 3 4	7	8.0	1600	4200	730	244	219	7.9	1600	3900	166	63	63
85 3 6	9	8.0	1450	4550	908	346	296	7.9	1450	3990	254	124	110
85 3 8	11	7.8	1500	5100	544	591	500	7.9	1450	3750	108	106	104
85 3 11	14	7.7	1550	5100	478	353	308	8.5	1550	3950	113	94	92
85 3 13	16	NA	1800	4700	487	235	227	NA	1450	3900	211	120	114
85 3 15	18	8.2	1800	4800	322	573	518	8.5	1450	3900	128	93	74
85 3 18	21	8.2	2000	5100	437	615	449	8.5	1700	3900	224	98	85
85 3 20	23	8.1	1950	4950	399	475	389	8.3	1550	3700	130	71	53
85 3 22	25	8.1	2050	4400	242	149	139	8.0	1650	3800	140	82	67
AVG			1695	4664	512	348	299		1509	3731	147	83	74
STD DEV			220	367	225	183	143		116	306	59	31	29
85 3 25	28	8.2	2000	4200	197	126	115	8.2	1750	3700	75	57	34
85 3 27	30	8.0	2000	4500	360	207	148	8.0	1620	3550	112	55	47
85 3 29	32	8.0	2100	4550	265	187	130	8.1	2020	4700	441	257	177
85 4 1	35	8.3	2150	4600	252	360	235	8.2	1850	4050	112	94	68
85 4 3	37	8.0	1900	4750	315	165	148	7.9	1650	3600	92	49	45
85 4 8	42	8.0	2000	4300	269	113	113	8.2	1750	3950	178	70	58
85 4 10	44	7.9	1700	4750	489	178	170	8.2	1450	3700	208	212	158
85 4 12	46	8.0	1750	4900	368	293	268	8.2	1400	3800	91	102	38
85 4 15	49	8.0	1700	4600	288	208	148	7.9	1450	4300	705	402	338
85 4 17	51	7.9	1650	5000	465	404	348	7.9	1250	3800	170	138	119
85 4 19	53	7.9	1650	4600	331	132	130	7.9	1350	3800	75	46	46
85 4 22	56	8.2	1800	5000	423	756	606	8.3	1400	3700	138	74	74
85 4 24	58	NA	NA	4600	483	408	408	NA	NA	3600	90	60	60
85 4 25	59	7.9	1600	NA	NA	NA	NA	8.1	1150	NA	NA	NA	NA
85 4 26	60	8.0	1450	4500	343	333	333	8.0	1050	3600	166	124	124
AVG			1818	4632	346	276	236		1510	3846	161	124	99
STD DEV			201	226	88	166	139		266	308	99	98	80
85 4 29	63	8.0	1450	4500	298	318	307	8.0	1100	4100	160	126	126
85 5 1	65	7.3	1300	4900	403	336	318	7.9	1200	4400	190	1092	958
85 5 3	67	7.8	1450	4750	382	232	220	7.8	1000	3750	177	208	176
85 5 6	70	8.2	1400	4750	318	150	150	7.8	1150	3800	285	284	284
85 5 8	72	7.6	1520	4500	314	167	167	7.6	980	4000	173	173	173
85 5 10	74	7.8	1350	4200	185	188	188	7.6	1087	4300	NA	400	400
85 5 13	77	8.6	1200	3800	220	183	183	8.2	750	4200	134	167	167
85 5 15	79	7.1	1200	4400	314	262	262	7.0	850	4000	191	282	256
85 5 17	81	7.8	1300	4250	247	228	214	7.6	900	3800	191	256	224
AVG			1352	4450	298	229	223		1002	4039	188	332	307
STD DEV			106	319	67	62	57		140	218	41	280	243

APPENDIX F

NITROGEN MASS BALANCES: NITRIFICATION-ACTIVATED SLUDGE MODELS #1 AND #2

TABLE F.1 TKN MASS BALANCE : NITRIFICATION - ACTIVATED SLUDGE MODEL # 1

DATE	DAY	FEED VOLUME (L)	FEED TKN IN (mg/L)	TKN MASS BALANCE TABLE TKN OUT (mg/L)	TKN IN (g)	TKN OUT (g)	TKN REM (g)
85 2 26	1	NA	NA	NA	NA	NA	NA
85 2 27	2	0.140	88.9	53.4	0.012	0.007	0.005
85 3 1	4	0.850	111	60.5	0.094	0.051	0.043
85 3 4	7	1.380	124	70.3	0.171	0.097	0.074
85 3 6	9	1.080	131	68.5	0.141	0.074	0.068
85 3 8	11	0.970	198	65.9	0.192	0.064	0.128
85 3 11	14	1.030	141	69.6	0.145	0.072	0.074
85 3 13	16	1.050	124	61.3	0.130	0.064	0.066
85 3 15	18	1.220	142	64.7	0.173	0.079	0.094
85 3 18	21	2.000	170	71.6	0.340	0.143	0.197
85 3 20	23	0.910	151	76.4	0.137	0.070	0.068
85 3 22	25	0.920	127	71.3	0.117	0.066	0.051
AVG			137	66.7			
STD DEV			28	6.1			
85 3 25	28	1.440	129	79.3	0.186	0.114	0.072
85 3 27	30	0.960	136	94.1	0.131	0.090	0.040
85 3 29	32	0.770	136	117.0	0.105	0.090	0.015
85 4 1	35	1.470	153	99.9	0.225	0.147	0.078
85 4 3	37	1.050	133	95.8	0.140	0.101	0.039
85 4 8	42	2.650	132	92.3	0.350	0.245	0.105
85 4 10	44	1.090	135	76.7	0.147	0.084	0.064
85 4 12	46	1.140	148	72.5	0.169	0.083	0.086
85 4 15	49	1.420	132	79.7	0.187	0.113	0.074
85 4 17	51	1.050	163	78.4	0.171	0.082	0.089
85 4 19	53	1.030	147	79.8	0.151	0.082	0.069
85 4 22	56	1.390	175	91.7	0.243	0.127	0.116
85 4 24	58	0.930	162	84.8	0.151	0.079	0.072
85 4 26	60	1.010	161	81.3	0.163	0.082	0.080
AVG			146	87.4			
STD DEV			14	11			
85 4 29	63	1.390	158	81.5	0.220	0.113	0.106
85 5 1	65	1.025	144	83.0	0.148	0.085	0.063
85 5 3	67	0.935	148	79.0	0.138	0.074	0.065
85 5 6	70	1.305	133	76.9	0.174	0.100	0.073
85 5 8	72	1.030	101	83.4	0.104	0.086	0.018
85 5 10	74	1.015	119	74.0	0.121	0.075	0.046
85 5 13	77	1.335	112	87.3	0.150	0.117	0.033
85 5 15	79	1.015	133	89.4	0.135	0.091	0.044
85 5 17	81	0.905	135	95.0	0.122	0.086	0.036
AVG			131	83.3			
STD DEV			17	6.1			

TABLE F.2 NH3-N MASS BALANCE : NITRIFICATION - ACTIVATED SLUDGE MODEL # 1

DATE	DAY	FEED VOLUME (L)	NH3-N MASS BALANCE TABLE NH3-N IN (mg/L)	NH3-N OUT (mg/L)	NH3-N IN (g)	NH3-N OUT (g)	NH3-N REM (g)
85 2 26	1	NA	NA	NA	NA	NA	NA
85 2 27	2	0.140	26.9	1.8	0.004	.000	0.004
85 3 1	4	0.850	38.3	6.8	0.033	0.006	0.027
85 3 4	7	1.380	42.8	17.1	0.059	0.024	0.035
85 3 6	9	1.080	45.3	4.1	0.049	0.004	0.044
85 3 8	11	0.970	49.0	1.7	0.048	0.002	0.046
85 3 11	14	1.030	53.0	3.1	0.055	0.003	0.051
85 3 13	16	1.050	53.0	2.4	0.056	0.003	0.053
85 3 15	18	1.220	52.5	3.6	0.064	0.004	0.060
85 3 18	21	2.000	57.6	3.7	0.115	0.007	0.108
85 3 20	23	0.910	56.5	1.3	0.051	0.001	0.050
85 3 22	25	0.920	58.3	0.5	0.054	.000	0.053
AVG			48.5	4.2			
STD DEV			9.1	4.4			
85 3 25	28	1.440	58.8	14.2	0.085	0.020	0.064
85 3 27	30	0.960	62.9	26.4	0.060	0.025	0.035
85 3 29	32	0.770	61.6	44.4	0.047	0.034	0.013
85 4 1	35	1.470	59.0	44.2	0.087	0.065	0.022
85 4 3	37	1.050	62.1	24.5	0.065	0.026	0.039
85 4 8	42	2.650	58.0	17.6	0.154	0.047	0.107
85 4 10	44	1.090	64.7	2.7	0.071	0.003	0.068
85 4 12	46	1.140	58.9	1.0	0.067	0.001	0.066
85 4 15	49	1.420	55.1	2.3	0.078	0.003	0.075
85 4 17	51	1.050	65.1	1.4	0.068	0.001	0.067
85 4 19	53	1.030	65.9	1.8	0.068	0.002	0.066
85 4 22	56	1.390	59.5	1.9	0.083	0.003	0.080
85 4 24	58	0.930	66.9	0.7	0.062	0.001	0.062
85 4 26	60	1.010	62.5	1.3	0.063	0.001	0.062
AVG			61.5	13.2			
STD DEV			3.3	15.4			
85 4 29	63	1.390	64.2	2.1	0.089	0.003	0.086
85 5 1	65	1.025	65.7	5.9	0.067	0.006	0.061
85 5 3	67	0.935	61.5	0.5	0.058	.000	0.057
85 5 6	70	1.305	55.1	0.8	0.072	0.001	0.071
85 5 8	72	1.030	48.3	3.5	0.050	0.004	0.046
85 5 10	74	1.015	54.5	9.0	0.055	0.009	0.046
85 5 13	77	1.335	43.7	22.7	0.058	0.030	0.028
85 5 15	79	1.015	55.0	30.4	0.056	0.031	0.025
85 5 17	81	0.905	59.5	29.9	0.054	0.027	0.027
AVG			56.4	11.6			
STD DEV			6.8	11.8			

TABLE F.3 NO3-N MASS BALANCE : NITRIFICATION - ACTIVATED SLUDGE MODEL # 1

DATE	DAY	FEED VOLUME (L)	NO3-N IN (mg/L)	NO3-N OUT (mg/L)	NO3-N MASS BALANCE TABLE NO3-N IN (g)	NO3-N OUT (g)	NO3-N REM (g)
85 2 26	1	NA	NA	NA	NA	NA	NA
85 2 27	2	0.140	2.3	36.8	.000	0.005	-0.005
85 3 1	4	0.850	1.9	18.2	0.002	0.015	-0.014
85 3 4	7	1.380	1.8	24.8	0.002	0.034	-0.032
85 3 6	9	1.080	1.8	1.9	0.002	0.002	.000
85 3 8	11	0.970	2.0	51.1	0.002	0.050	-0.048
85 3 11	14	1.030	1.5	44.0	0.002	0.045	-0.044
85 3 13	16	1.050	2.4	46.9	0.003	0.049	-0.047
85 3 15	18	1.220	2.1	38.7	0.003	0.047	-0.045
85 3 18	21	2.000	2.5	48.4	0.005	0.097	-0.092
85 3 20	23	0.910	2.7	71.8	0.002	0.065	-0.063
85 3 22	25	0.920	2.6	71.4	0.002	0.066	-0.063
AVG			2.1	41.3			
STD DEV			0.4	20.0			
85 3 25	28	1.440	2.2	39.4	0.003	0.057	-0.054
85 3 27	30	0.960	3.6	21.1	0.003	0.020	-0.017
85 3 29	32	0.770	2.7	2.7	0.002	0.002	0.000
85 4 1	35	1.470	2.7	8.9	0.004	0.013	-0.009
85 4 3	37	1.050	2.7	28.7	0.003	0.030	-0.027
85 4 8	42	2.650	3.5	22.1	0.009	0.059	-0.049
85 4 10	44	1.090	3.6	59.7	0.004	0.065	-0.061
85 4 12	46	1.140	4.1	64.2	0.005	0.073	-0.069
85 4 15	49	1.420	5.8	68.5	0.008	0.097	-0.089
85 4 17	51	1.050	4.4	85.5	0.005	0.090	-0.085
85 4 19	53	1.030	4.3	79.8	0.004	0.082	-0.078
85 4 22	56	1.390	3.4	77.2	0.005	0.107	-0.103
85 4 24	58	0.930	4.0	88.2	0.004	0.082	-0.078
85 4 26	60	1.010	3.8	90.5	0.004	0.091	-0.088
AVG			3.6	52.6			
STD DEV			0.9	30.0			
85 4 29	63	1.390	3.3	79.4	0.005	0.110	-0.106
85 5 1	65	1.025	3.5	61.5	0.004	0.063	-0.059
85 5 3	67	0.935	3.1	72.3	0.003	0.068	-0.065
85 5 6	70	1.305	3.2	68.5	0.004	0.089	-0.085
85 5 8	72	1.030	3.0	65.3	0.003	0.067	-0.064
85 5 10	74	1.015	3.0	40.8	0.003	0.041	-0.038
85 5 13	77	1.335	2.5	15.9	0.003	0.021	-0.018
85 5 15	79	1.015	2.6	14.0	0.003	0.014	-0.012
85 5 17	81	0.905	2.7	17.1	0.002	0.015	-0.013
AVG			3.0	48.3			
STD DEV			0.3	25.1			

TABLE F.4 NO2-N MASS BALANCE : NITRIFICATION - ACTIVATED SLUDGE MODEL # 1

DATE	DAY	FEED VOLUME (L)	NO2-N MASS BALANCE TABLE NO2-N IN (mg/L)	NO2-N OUT (mg/L)	NO2-N IN (g)	NO2-N OUT (g)	NO2-N REM (g)
85 2 26	1	NA	NA	NA	NA	NA	NA
85 2 27	2	0.140	0.1	1.0	.000	.000	.000
85 3 1	4	0.850	0.1	4.0	.000	0.003	-0.003
85 3 4	7	1.380	0.1	0.1	.000	.000	0.000
85 3 6	9	1.080	0.1	7.3	.000	0.008	-0.008
85 3 8	11	0.970	0.1	1.2	.000	0.001	-0.001
85 3 11	14	1.030	0.1	1.1	.000	0.001	-0.001
85 3 13	16	1.050	0.1	1.2	.000	0.001	-0.001
85 3 15	18	1.220	0.1	1.3	.000	0.002	-0.001
85 3 18	21	2.000	0.1	1.4	.000	0.003	-0.003
85 3 20	23	0.910	0.1	0.6	.000	0.001	.000
85 3 22	25	0.920	0.1	0.8	.000	0.001	-0.001
AVG			0.1	1.8			
STD DEV			0.0	2.0			
85 3 25	28	1.440	0.1	4.5	.000	0.006	-0.006
85 3 27	30	0.960	0.1	3.1	.000	0.003	-0.003
85 3 29	32	0.770	0.1	0.0	.000	0.000	.000
85 4 1	35	1.470	0.1	4.8	.000	0.007	-0.007
85 4 3	37	1.050	0.1	10.5	.000	0.011	-0.011
85 4 8	42	2.650	0.1	13.3	.000	0.035	-0.035
85 4 10	44	1.090	0.1	7.2	.000	0.008	-0.008
85 4 12	46	1.140	0.1	0.7	.000	0.001	-0.001
85 4 15	49	1.420	0.1	0.9	.000	0.001	-0.001
85 4 17	51	1.050	0.1	0.5	.000	0.001	.000
85 4 19	53	1.030	0.1	0.8	.000	0.001	-0.001
85 4 22	56	1.390	0.1	1.8	.000	0.003	-0.002
85 4 24	58	0.930	0.1	0.9	.000	0.001	-0.001
85 4 26	60	1.010	0.1	0.6	.000	0.001	-0.001
AVG			0.1	3.5			
STD DEV			0.0	4.0			
85 4 29	63	1.390	0.1	1.9	.000	0.003	-0.003
85 5 1	65	1.025	0.1	1.3	.000	0.001	-0.001
85 5 3	67	0.935	0.1	0.5	.000	.000	.000
85 5 6	70	1.305	0.1	0.8	.000	0.001	-0.001
85 5 8	72	1.030	0.1	0.7	.000	0.001	-0.001
85 5 10	74	1.015	0.1	2.4	.000	0.002	-0.002
85 5 13	77	1.335	0.1	2.3	.000	0.003	-0.003
85 5 15	79	1.015	0.1	2.3	.000	0.002	-0.002
85 5 17	81	0.905	0.1	3.3	.000	0.003	-0.003
AVG			0.1	1.7			
STD DEV			0.0	0.9			

TABLE F.5 TKN MASS BALANCE : NITRIFICATION - ACTIVATED SLUDGE MODEL # 2

DATE	DAY	FEED VOLUME (L)	FEED TKN IN (mg/L)	TKN MASS BALANCE TABLE TKN OUT (mg/L)	TKN IN (g)	TKN OUT (g)	TKN REM (g)
85 2 26	1	NA	NA	NA	NA	NA	NA
85 2 27	2	0.150	88.9	51.5	0.013	0.008	0.006
85 3 1	4	0.910	111	56.5	0.101	0.051	0.050
85 3 4	7	1.440	124	83.5	0.179	0.120	0.058
85 3 6	9	1.100	131	93.0	0.144	0.102	0.042
85 3 8	11	1.030	198	76.9	0.204	0.079	0.125
85 3 11	14	1.190	141	81.0	0.168	0.096	0.071
85 3 13	16	1.060	124	77.0	0.131	0.082	0.050
85 3 15	18	1.270	142	69.3	0.180	0.088	0.092
85 3 18	21	2.140	170	88.6	0.364	0.190	0.174
85 3 20	23	0.990	151	77.2	0.149	0.076	0.073
85 3 22	25	0.920	127	75.3	0.117	0.069	0.048
AVG			137	75.4			
STD DEV			28	11.9			
85 3 25	28	1.520	129	71.7	0.196	0.109	0.087
85 3 27	30	1.040	136	72.4	0.141	0.075	0.066
85 3 29	32	0.800	136	118.0	0.109	0.094	0.014
85 4 1	35	1.470	153	78.4	0.225	0.115	0.110
85 4 3	37	1.170	133	69.8	0.156	0.082	0.074
85 4 8	42	2.820	132	74.4	0.372	0.210	0.162
85 4 10	44	1.120	135	81.7	0.151	0.092	0.060
85 4 12	46	1.260	148	65.0	0.186	0.082	0.105
85 4 15	49	1.510	132	98.2	0.199	0.148	0.051
85 4 17	51	1.080	163	79.2	0.176	0.086	0.091
85 4 19	53	1.040	147	77.3	0.153	0.080	0.072
85 4 22	56	1.510	175	83.8	0.264	0.127	0.138
85 4 24	58	1.020	162	82.4	0.165	0.084	0.081
85 4 26	60	1.140	161	76.9	0.184	0.088	0.096
AVG			146	80.7			
STD DEV			14	12.8			
85 4 29	63	1.390	158	91.1	0.220	0.127	0.093
85 5 1	65	1.150	144	93.5	0.166	0.108	0.058
85 5 3	67	0.975	148	81.4	0.144	0.079	0.065
85 5 6	70	1.410	133	91.4	0.188	0.129	0.059
85 5 8	72	1.055	101	82.7	0.107	0.087	0.019
85 5 10	74	0.620	119	NA	0.074	NA	NA
85 5 13	77	1.455	112	81.8	0.163	0.119	0.044
85 5 15	79	1.000	133	79.2	0.133	0.079	0.054
85 5 17	81	0.960	135	87.7	0.130	0.084	0.045
AVG			131	86.1			
STD DEV			17	5.1			

TABLE F.6 NH3-N MASS BALANCE : NIRIFICATION - ACTIVATED SLUDGE MODEL # 2

DATE	DAY	FEED VOLUME (L)	NH3-N MASS BALANCE TABLE NH3-N IN (mg/L)	NH3-N OUT (mg/L)	NH3-N IN (g)	NH3-N OUT (g)	NH3-N REM (g)
85 2 26	1	NA	NA	NA	NA	NA	NA
85 2 27	2	0.150	26.9	0.8	0.004	.000	0.004
85 3 1	4	0.910	38.3	4.6	0.035	0.004	0.031
85 3 4	7	1.440	42.8	27.0	0.062	0.039	0.023
85 3 6	9	1.100	45.3	24.2	0.050	0.027	0.023
85 3 8	11	1.030	49.0	17.1	0.050	0.018	0.033
85 3 11	14	1.190	53.0	13.4	0.063	0.016	0.047
85 3 13	16	1.060	53.0	2.7	0.056	0.003	0.053
85 3 15	18	1.270	52.5	5.6	0.067	0.007	0.060
85 3 18	21	2.140	57.6	26.1	0.123	0.056	0.067
85 3 20	23	0.990	56.5	2.0	0.056	0.002	0.054
85 3 22	25	0.920	58.3	0.5	0.054	.000	0.053
AVG			48.5	11.3			
STD DEV			9.1	10.2			
85 3 25	28	1.520	58.8	2.0	0.089	0.003	0.086
85 3 27	30	1.040	62.9	2.3	0.065	0.002	0.063
85 3 29	32	0.800	61.6	33.0	0.049	0.026	0.023
85 4 1	35	1.470	59.0	33.0	0.087	0.049	0.038
85 4 3	37	1.170	62.1	1.3	0.073	0.002	0.071
85 4 8	42	2.820	58.0	7.2	0.164	0.020	0.143
85 4 10	44	1.120	64.7	1.3	0.072	0.001	0.071
85 4 12	46	1.260	58.9	2.1	0.074	0.003	0.072
85 4 15	49	1.510	55.1	3.3	0.083	0.005	0.078
85 4 17	51	1.080	65.1	2.0	0.070	0.002	0.068
85 4 19	53	1.040	65.9	6.1	0.069	0.006	0.062
85 4 22	56	1.510	59.5	7.4	0.090	0.011	0.079
85 4 24	58	1.020	66.9	1.0	0.068	0.001	0.067
85 4 26	60	1.140	62.5	1.1	0.071	0.001	0.070
AVG			61.5	7.4			
STD DEV			3.3	10.7			
85 4 29	63	1.390	64.2	6.7	0.089	0.009	0.080
85 5 1	65	1.150	65.7	15.9	0.076	0.018	0.057
85 5 3	67	0.975	61.5	0.5	0.060	.000	0.059
85 5 6	70	1.410	55.1	0.6	0.078	0.001	0.077
85 5 8	72	1.055	48.3	1.0	0.051	0.001	0.050
85 5 10	74	0.620	54.5	NA	0.034	NA	NA
85 5 13	77	1.455	43.7	4.2	0.064	0.006	0.057
85 5 15	79	1.000	55.0	1.0	0.055	0.001	0.054
85 5 17	81	0.960	59.5	1.6	0.057	0.002	0.056
AVG			56.4	3.9			
STD DEV			6.8	5.0			

TABLE F.7 NO3-N MASS BALANCE : NIRIFICATION - ACTIVATED SLUDGE MODEL # 2

DATE	DAY	FEED VOLUME (L)	NO3-N IN (mg/L)	NO3-N OUT (mg/L)	NO3-N MASS BALANCE TABLE NO3-N IN (g)	NO3-N OUT (g)	NO3-N REM (g)
85 2 26	1	NA	NA	NA	NA	NA	NA
85 2 27	2	0.150	2.3	32.8	.000	0.005	-0.005
85 3 1	4	0.910	1.9	2.0	0.002	0.002	.000
85 3 4	7	1.440	1.8	20.5	0.003	0.030	-0.027
85 3 6	9	1.100	1.8	1.9	0.002	0.002	.000
85 3 8	11	1.030	2.0	4.0	0.002	0.004	-0.002
85 3 11	14	1.190	1.5	5.8	0.002	0.007	-0.005
85 3 13	16	1.060	2.4	43.5	0.003	0.046	-0.044
85 3 15	18	1.270	2.1	43.5	0.003	0.055	-0.053
85 3 18	21	2.140	2.5	5.5	0.005	0.012	-0.006
85 3 20	23	0.990	2.7	59.0	0.003	0.058	-0.056
85 3 22	25	0.920	2.6	66.9	0.002	0.062	-0.059
AVG			2.1	25.9			
STD DEV			0.4	23.2			
85 3 25	28	1.520	2.2	57.7	0.003	0.088	-0.084
85 3 27	30	1.040	3.6	70.7	0.004	0.074	-0.070
85 3 29	32	0.800	2.7	14.9	0.002	0.012	-0.010
85 4 1	35	1.470	2.7	45.5	0.004	0.067	-0.063
85 4 3	37	1.170	2.7	63.2	0.003	0.074	-0.071
85 4 8	42	2.820	3.5	48.9	0.010	0.138	-0.128
85 4 10	44	1.120	3.6	71.6	0.004	0.080	-0.076
85 4 12	46	1.260	4.1	56.0	0.005	0.071	-0.065
85 4 15	49	1.510	5.8	53.3	0.009	0.080	-0.072
85 4 17	51	1.080	4.4	66.7	0.005	0.072	-0.067
85 4 19	53	1.040	4.3	47.1	0.004	0.049	-0.045
85 4 22	56	1.510	3.4	48.4	0.005	0.073	-0.068
85 4 24	58	1.020	4.0	77.7	0.004	0.079	-0.075
85 4 26	60	1.140	3.8	74.0	0.004	0.084	-0.080
AVG			3.6	56.8			
STD DEV			0.9	15.6			
85 4 29	63	1.390	3.3	57.6	0.005	0.080	-0.075
85 5 1	65	1.150	3.5	42.6	0.004	0.049	-0.045
85 5 3	67	0.975	3.1	69.3	0.003	0.068	-0.065
85 5 6	70	1.410	3.2	64.6	0.005	0.091	-0.087
85 5 8	72	1.055	3.0	81.0	0.003	0.085	-0.082
85 5 10	74	0.620	3.0	NA	0.002	NA	NA
85 5 13	77	1.455	2.5	51.1	0.004	0.074	-0.071
85 5 15	79	1.000	2.6	70.5	0.003	0.071	-0.068
85 5 17	81	0.960	2.7	76.4	0.003	0.073	-0.071
AVG			3.0	64.1			
STD DEV			0.3	12.1			

TABLE F.8 NO2-N MASS BALANCE : NIRIFICATION - ACTIVATED SLUDGE MODEL # 2

DATE	DAY	FEED VOLUME (L)	NO2-N MASS BALANCE TABLE NO2-N IN (mg/L)	NO2-N OUT (mg/L)	NO2-N IN (g)	NO2-N OUT (g)	NO2-N REM (g)
85 2 26	1	NA	NA	NA	NA	NA	NA
85 2 27	2	0.150	0.1	1.0	.000	.000	.000
85 3 1	4	0.910	0.1	2.8	.000	0.003	-0.002
85 3 4	7	1.440	0.1	0.1	.000	.000	0.000
85 3 6	9	1.100	0.1	0.2	.000	.000	.000
85 3 8	11	1.030	0.1	2.1	.000	0.002	-0.002
85 3 11	14	1.190	0.1	2.4	.000	0.003	-0.003
85 3 13	16	1.060	0.1	7.1	.000	0.008	-0.007
85 3 15	18	1.270	0.1	4.6	.000	0.006	-0.006
85 3 18	21	2.140	0.1	1.9	.000	0.004	-0.004
85 3 20	23	0.990	0.1	2.5	.000	0.002	-0.002
85 3 22	25	0.920	0.1	1.3	.000	0.001	-0.001
AVG			0.1	2.4			
STD DEV			0.0	1.9			
85 3 25	28	1.520	0.1	4.7	.000	0.007	-0.007
85 3 27	30	1.040	0.1	0.5	.000	0.001	.000
85 3 29	32	0.800	0.1	2.5	.000	0.002	-0.002
85 4 1	35	1.470	0.1	3.3	.000	0.005	-0.005
85 4 3	37	1.170	0.1	1.2	.000	0.001	-0.001
85 4 8	42	2.820	0.1	1.7	.000	0.005	-0.005
85 4 10	44	1.120	0.1	0.6	.000	0.001	-0.001
85 4 12	46	1.260	0.1	0.7	.000	0.001	-0.001
85 4 15	49	1.510	0.1	1.9	.000	0.003	-0.003
85 4 17	51	1.080	0.1	0.9	.000	0.001	-0.001
85 4 19	53	1.040	0.1	2.2	.000	0.002	-0.002
85 4 22	56	1.510	0.1	2.9	.000	0.004	-0.004
85 4 24	58	1.020	0.1	1.1	.000	0.001	-0.001
85 4 26	60	1.140	0.1	0.9	.000	0.001	-0.001
AVG			0.1	1.8			
STD DEV			0.0	1.2			
85 4 29	63	1.390	0.1	2.8	.000	0.004	-0.004
85 5 1	65	1.150	0.1	2.6	.000	0.003	-0.003
85 5 3	67	0.975	0.1	0.7	.000	0.001	-0.001
85 5 6	70	1.410	0.1	1.5	.000	0.002	-0.002
85 5 8	72	1.055	0.1	0.8	.000	0.001	-0.001
35 5 10	74	0.620	0.1	NA	.000	NA	NA
85 5 13	77	1.455	0.1	1.8	.000	0.003	-0.002
85 5 15	79	1.000	0.1	0.9	.000	0.001	-0.001
85 5 17	81	0.960	0.1	1.3	.000	0.001	-0.001
AVG			0.1	1.6			
STD DEV			0.0	0.7			

APPENDIX G

CARBONACEOUS AND SOLIDS REMOVALS: NITRIFICATION-ACTIVATED SLUDGE MODELS #1 AND #2

TABLE G.1 : CARBONACEOUS AND SOLIDS REMOVALS : NITRIFICATION - ACTIVATED SLUDGE MODEL # 1

DATE	DAY	REMOVALS (%) COD	BOD	SS	VSS
85 2 26	1	NA	NA	NA	NA
85 2 27	2	20.0	61.0	61.2	61.2
85 3 1	4	22.7	93.7	86.4	86.9
85 3 4	7	19.0	89.2	77.5	76.7
85 3 6	9	22.0	79.8	69.4	72.6
85 3 8	11	32.4	78.9	85.8	87.6
85 3 11	14	26.5	77.6	73.7	79.9
85 3 13	16	24.5	79.5	52.3	55.9
85 3 15	18	25.0	66.5	74.5	76.6
85 3 18	21	30.4	67.5	80.8	75.9
85 3 20	23	31.3	82.0	92.0	91.5
85 3 22	25	21.6	73.1	71.1	76.3
AVG		25.0	77.2	75.0	76.5
STD DEV		4.4	9.3	11.0	10.2
85 3 25	28	15.5	64.0	68.3	73.0
85 3 27	30	15.6	62.5	51.7	45.9
85 3 29	32	9.9	24.5	0.0	0.0
85 4 1	35	5.4	56.3	56.7	47.2
85 4 3	37	15.8	74.3	64.8	60.8
85 4 8	42	8.1	53.5	37.2	37.2
85 4 10	44	17.9	81.6	76.4	75.3
85 4 12	46	18.4	84.2	89.1	88.1
85 4 15	49	15.2	49.3	0.0	0.0
85 4 17	51	30.0	75.1	70.8	72.1
85 4 19	53	15.2	62.2	0.0	0.0
85 4 22	56	28.0	73.0	81.7	80.7
85 4 24	58	21.7	79.5	69.9	69.9
85 4 26	60	22.2	76.4	76.6	76.6
AVG		17.1	65.5	53.1	51.9
STD DEV		6.6	15.4	30.4	30.4
85 4 29	63	11.1	69.1	76.1	75.2
85 5 1	65	23.5	69.5	68.8	67.0
85 5 3	67	22.1	58.9	24.1	20.0
85 5 6	70	17.9	56.0	71.3	71.3
85 5 8	72	8.9	30.3	0.0	0.0
85 5 10	74	10.7	65.9	60.1	60.1
85 5 13	77	5.3	62.3	34.4	34.4
85 5 15	79	13.6	72.6	53.4	56.5
85 5 17	81	16.5	46.6	51.8	57.0
AVG		14.4	59.0	48.9	49.1
STD DEV		5.7	12.7	23.6	24.1

TABLE G.2 : CARBONACEOUS AND SOLIDS REMOVALS :
NITRIFICATION - ACTIVATED SLUDGE MODEL # 2

DATE	DAY	REMOVALS (%)			
		COD	BOD	SS	VSS
85 2 26	1	NA	NA	NA	NA
85 2 27	2	26.3	56.7	32.8	43.3
85 3 1	4	25.0	94.3	90.3	90.3
85 3 4	7	7.1	77.3	74.2	71.2
85 3 6	9	12.3	72.0	64.2	62.8
85 3 8	11	26.5	80.1	82.1	79.2
85 3 11	14	22.5	76.4	73.4	70.1
85 3 13	16	17.0	56.7	48.9	49.8
85 3 15	18	18.8	60.2	83.8	85.7
85 3 18	21	23.5	48.7	84.1	81.1
85 3 20	23	25.3	67.4	85.1	86.4
85 3 22	25	13.6	42.1	45.0	51.8
AVG		19.8	66.5	69.4	70.2
STD DEV		6.2	14.6	18.3	15.5
85 3 25	28	11.9	61.9	54.8	70.4
85 3 27	30	21.1	68.9	73.4	68.2
85 3 29	32	0.0	0.0	0.0	0.0
85 4 1	35	12.0	55.6	73.9	71.1
85 4 3	37	24.2	70.8	70.3	69.6
85 4 8	42	8.1	33.8	38.1	48.7
85 4 10	44	22.1	57.5	0.0	7.1
85 4 12	46	22.4	75.3	65.2	85.8
85 4 15	49	6.5	0.0	0.0	0.0
85 4 17	51	24.0	63.4	65.8	65.8
85 4 19	53	17.4	77.3	65.2	64.6
85 4 22	56	26.0	67.4	90.2	87.8
85 4 24	58	21.7	81.4	85.3	85.3
85 4 26	60	20.0	51.6	62.8	62.8
AVG		17.0	54.6	53.2	56.2
STD DEV		7.6	25.1	30.2	29.8
85 4 29	63	8.9	46.3	60.4	59.0
85 5 1	65	10.2	52.9	0.0	0.0
85 5 3	67	21.1	53.7	10.3	20.0
85 5 6	70	20.0	10.4	0.0	0.0
85 5 8	72	11.1	44.9	0.0	0.0
85 5 10	74	0.0	NA	0.0	0.0
85 5 13	77	0.0	39.1	8.7	8.7
85 5 15	79	9.1	39.2	0.0	2.3
85 5 17	81	10.6	22.7	0.0	0.0
AVG		10.1	38.6	8.8	10.0
STD DEV		6.9	14.1	18.6	18.4

APPENDIX H

PRELIMINARY, FULL-SCALE BVF DESIGN CRITERIA AND ASSUMPTIONS

1. Wastewater Data

   A. Maine Project

   Q = 14 700 m^3/d
   COD/BOD/SS = 13 400/5500/1000 mg/L
   Temperature TO BVF = 35-40°C

   B. Barrington Project

   Q = 450 m^3/d
   COD/BOD/SS = 13 400/5500/1000 mg/L
   Temperature to BVF = 35-40°C

2. BVF Design Criteria - 65/85 percent COD/BOD removal for loading of 2.0 kg COD/m^3.d

3. Nutrient Requirements - none

4. pH Control - Chemical addition will be required
   Assume 100 mg/L NaOH on a continuing basis
   (allow $250/t for NaOH)

5. Methane Yield - 0.27 m^3 (STP)/kg COD removed

6. Wet-Carb Plant Operation - 24 h/d, 250 d/a

7. Treatment Plant Operation - 24 h/d, 365 d/a

8. Cost of Electricity - 5¢/kWh

9. Treatment Plant Staffing requirements (for anaerobic and aerobic) - one foreman on day shift, one operator required around the clock, one environmental technician, one shift per day 5 days per week for analytical testing; no allowance for supervision or administration

10. No allowance for land costs for treatment.

11. No allowance for cooling of BVF influent if required.

12. No allowance for pumping station and force main to BVF.

13. BVF requires 12 mm of insulation in cover.

14. Allow for complete system for biogas collection and utilization.

15. Assume biogas force main of 330 metres.

16. Allow $150 000 and $20 000 for boiler modifications to burn biogas for the Maine and Barrington projects, respectively.

17. Assume suitable clay material is available within 5 km of site for BVFs basin construction.

18. Allow for steam line (live steam injection) to BVF influent chambers for start-up and emergency heating.

19. No allowance for aerobic treatment.

20. No allowance for any outfall.

21. No allowance for local taxes and insurance.

22. Allow 1.5 and 2.5 percent of BVF capital costs for maintenance costs for the Maine and Barrington projects, respectively.

23. Allow 30 and 5 kW for BVF mixing and sludge recycle, and 50 and 5 kW for biogas blowers (continuous load) for the Maine and Barrington projects, respectively.

APPENDIX I

PRELIMINARY BVF CAPITAL COST ESTIMATE (1985$)

		Barrington* $	Maine* $
1.	Mobilization, all earthwork and misc. site work	19 000	281 000
2.	BVF inlet/outlet/recycle systems and structures, misc. piping and valves, sludge recycle/wasting system	41 000	442 000
3.	BVF reinforced concrete wall and membrane/clay liner	133 000	1 140 000
4.	Biogas collection perimeter piping	12 500	187 000
5.	BVF membrane cover c/w 12 mm insulation, access hatches and sampling ports	47 000	915 000
6.	Slow-speed mixers	15 000	90 000
7.	BVF monitoring and controls	39 000	50 000
8.	Biogas blower building c/w duplex blowers, monitoring equipment, controls and control valves, safety vent and flare system	72 000	245 000
9.	Biogas main to boiler house c/w condensation traps and allowance for boiler retrofit	32 500	225 000
10.	Caustic storage and feed system	25 000	75 000
11.	Electrical	35 000	250 000
12.	Start-up chemicals and seed sludge allowance and heating allowance	23 000	90 000
	Subtotal	494 000	3 990 000

13.	Engineering** and contingencies @ 35% and 30% for Barrington and Maine projects, respectively	173 000	1 197 000
	TOTAL	$667 000	$5 187 000

*Maine project - 2 BVFs @ 50 000 m^3 each;
Barrington project - 1 BVF @ 3000 m^3

(**Includes preliminary, detailed design, construction and inspection, and commissioning and start-up services)

APPENDIX J

PROJECTED ANNUAL OPERATING AND MAINTENANCE COST ESTIMATES (1985$) (BVF ONLY)

		Barrington $	Maine $
1.	Operators (4 shift positions and one foreman)	150 000	150 000
2.	Environmental technician (1 shift position)*	35 000	35 000
3.	Electrical power costs	5 000	35 000

		Maine	Barrington
(a)	BVF mixers	15 kW	2 kW
(b)	Effluent to sludge recycle pumps	15 kW	3 kW
(c)	Biogas blowers	50 kW	5 kW
		80 kW	10 kW

4.	Nutrients	Nil	Nil
5.	pH control chemicals**	3 000	100 000
6.	Maintenance	17 000	77 000
7.	Miscellaneous allowance	5 000	50 000
	TOTAL	$ 215 000	447 000

* should be adequate for operation of aerobic system also

** allowance for heat and start-up chemicals included in capital cost